INSTREAM PROTECTED USES, OUTSTANDING CHARACTERISTICS, AND RESOURCES OF THE LAMPREY RIVER AND PROPOSED PROTECTIVE FLOW MEASURES FOR FLOW DEPENDENT RESOURCES

DRAFT REPORT

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R-20371.000

December 2005

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1.0 INTRODUCTION AND PURPOSE

The primary objective of this effort is to establish a comprehensive list of flow dependent Instream Protected Uses, Outstanding Characteristics and Resources (IPUOCR) entities for the designated reach of the Lamprey River and to propose methods for assessing their flow dependence. Based on their seasonal flow requirements, these IPUOCR entities will serve as guideposts for designating protected instream flows. The IPUOCR's evaluated included the list developed by the New Hampshire Department of Environmental Services (NHDES 2004) as a starting point augmented by literature searches, stakeholder consultation and a field visit. Such information included but was not limited to designated river nomination reports, river corridor management plans, natural resources studies, natural heritage inventories and environmental assessments and impact statements. A preliminary draft IPUOCR list was created in August 2005. The preliminary draft IPUOCR list and supporting information was refined following review and comment by DES and the advisory committee and is the basis for the discussion of resources in this final IPUOCR report. In this report, the development of the final IPUOCR list is described. The final IPUOCR list was divided into flow dependent and non-flow dependent entities. Protected flows will not be determined for the non-flow dependent entities. Approaches for establishing protected instream flows (PISF) for flow dependent IPUOCR are presented in Section 3.1. Non-flow dependent entities are identified in Section 3.2.

2.0 METHODS OF ASSESSMENT

2.1 OVERVIEW OF ALL POTENTIAL IPUOCRS

The New Hampshire Department of Environmental Services (DES) has defined the categories of Instream Public Uses, Outstanding Characteristics, and Resources that must be evaluated and included in the development of a PISF Study and eventual Water Management Plan (WMP). Categories of potential IPUOCR include the following:

Navigation: The use of the river for non-recreational, transportation purposes.

Recreation: Use of the river for swimming, boating or significant shoreland recreation such as hiking, camping, picnicking and bird watching.

Fishing: Both Recreational Use and Commercial Use

Storage: Natural or man-made attributes of a river for water storage.

Conservation/Open Space**:** Issues concerning management of open space, conservation easements or municipal, state or federal parks.

Maintenance and Enhancement of Aquatic and Fish Life*:* Those aquatic-dependent species that make up a balanced, integrated and adaptive community of organisms having a species composition, diversity and functional organization comparable to that of similar natural habitats of a region.

Fish and Wildlife Habitat: Species that rely on flow and flow to regions which are important to the survival of fish and wildlife populations, including but not limited to: spawning and feeding beds, waterfowl breeding or wintering areas, freshwater wetlands or riparian habitat.

Rare, Threatened or Endangered (RTE): fish, wildlife, vegetation or natural/ecological communities: As listed by New Hampshire Natural Heritage Inventory (NHI) and nomination papers.

Water Quality Protection/Public Health: Characteristics that maintain water quality of the river including, but not limited to, chemical and physical parameters that support designated and existing uses.

Public Water Supply: An existing source of public drinking water as defined in Env-Ws 302.02.

Pollution Abatement**:** Wastewater treatment facilities or industrial treatment facilities and aspects of flow affecting assumptions of flow for dilution and dispersal of waste in mixing zones and the river's overall capacity to mitigate natural and non-point source contamination.

Aesthetic Beauty/Scenic: Including but not limited to designated viewing areas, scenic vistas and overlooks.

Cultural: On-going river corridor management planning effort or other local efforts to protect or manage the river, riverside parks or other public areas, or community support for riverfront revitalization.

Historical or Archaeological: Based on the presence or absence of known historical or archaeological resources.

Community Significance: A natural, managed, cultural or recreational resource or use thereof associated with the river that is recognized by local residents or a municipal document as being important to the community adjacent to the river.

Hydrological/Geological*:* A national, regional, state or local resource as determined by the state geologist or as listed in a national or state resource assessment.

Agricultural**:** As defined by RSA 21:34a.

2.2 DRAFT LIST OF IPUOCR ENTITIES

From the universe of potential IPUOCR, the project team developed in August 2005 a draft list that included IPUOCR that were confirmed to be present along the designated reach or suspected to be present. Natural history and location information was reviewed for each IPUOCR entity, and compared to initial criteria for assigning an IPUOCR plant or wildlife species or natural community or other entity to a flow-dependency category. The criteria were:

Flow-Dependent – Species with one or more life stages requiring shallow standing/flowing water within banks of the river channel of the designated reach during summer; or a community that provides habitat for such species as an important function were included in this category. Other entities such as canoeing and kayaking were included in this category if they were determined to be reliant on flow.

Potentially Flow-Dependent – Entities with an unclear link to flow were included in this category as well as entities with known flow dependence but unknown or unconfirmed presence in the designated reach. A determination of flow dependence was made for these entities after further literature review and the site visit.

Non Flow-Dependent – Entities in this category met none of the above criteria. The life cycles of species or activities associated with the entities in this category were not dependent on water flow or levels within the river channel or floodplain of the designated reach at any time of the year. These entities do not depend on flow.

The draft list was delivered to NHDES on August 18, 2005 and subsequently distributed within the NHDES, to the technical review committee (TRC), and the Water Management Planning Area Advisory Committee (WMPAAC). There were few comments received on the draft list therefore the draft list and observations from the site visit formed the basis for the final list of IPUOCR for the designated reach of the Lamprey River. This list was delivered to the NHDES on September 23, 2005 and subsequently distributed to the members of the WMPAAC and TRC. The draft final IPUOCR list was presented to the WMPAAC on October 7, 2005 at a public meeting in Raymond, NH. The draft final list reclassified potentially flow dependent resources into either flow dependent or non-flow dependent categories.

2.3 LITERATURE REVIEW

Numerous sources of information describing the resources of the Lamprey River have been reviewed including the Lamprey Wild and Scenic River Report (LWSRS 1995), several reports detailing Lamprey river ecology, and water monitoring data (NHDES 1995). Other available information reviewed included NRCS soil maps, National Wetland Inventory maps, geologic resource maps, GRANIT GIS layers and aerial photos.

The review of available information was structured to develop the information base necessary to prepare a preliminary list of IPUOCR entities for the designated reach and to annotate each entity on the basis of river location and dependence on flow conditions. This preliminary list was confirmed to the extent possible and supplemented, where necessary, through consultation with state and local government and the field survey.

2.4 CONSULTATION

Agencies and organizations contacted by NAI or the NHDES included groups such as Lamprey Technical Review Committee and Water Management Area Advisory Committee members, New Hampshire Natural Heritage, Lamprey River Advisory Committee, Lamprey River Watershed Association, New Hampshire Fish and Game and the relevant conservation commissions. New information from these groups was added to the GIS database and used to describe the IPUOCR entities.

2.5 FIELD SURVEY

An on-stream survey was conducted August 25-26, 2005 to verify the existence and occurrence of the IPUOCR entities. The purpose of the instream habitat and aquatic fauna survey of the Lamprey River was to identify instream public uses, outstanding characteristics and resources (IPUOCR's). This 2 day field survey of the entire designated reach included stops at specific prescreened locations to document the presence of each entity or the presence of conditions or habitat suitable for each entity. Candidate locations for field verification were determined from data compiled by NHDES, New Hampshire Natural Heritage data and information obtained from watershed groups. The intent was to ensure that examples of critical locations of flow dependent or potentially flow dependent resources were visited.

The riparian and upland survey was guided by a set of maps which presented the available geographic information on the critical resources of the designated reach along with points to be visited. At each stop, the resources on the map were confirmed and photo documented according to the NHDES photo documentation procedures. The photos were geo-referenced using GPS and added as a layer to the GIS database (Figures 2-1, 2-2). Occurrences of resources not represented in the existing database were documented.

Due to delays in contracting as well as to the dramatic increase in river flow associated with rain events and water releases from the upstream lakes and ponds, detailed survey of instream habitat distribution had to be postponed to the next field season for reasons of safety. Three reconnaissance level visits were conducted on February 18, 2005, October 3, 2005 and November 18, 2005.

2.6 Delineations of Sections and Reaches

Based on on-the-ground observations together with analysis of high resolution aerial photographs taken in February 2005, we were able to delineate the designated river reach into seven sections, depicting key habitat characteristics. In these sections, similar habitats and species could be assumed to be potentially present.

2.7 Screening Methods

The IPUOCR list contained in the draft was augmented with a literature review and observations from the field reconnaissance survey. The revised list was then split into two categories based on the dependence of the entity on stream flow. These categories were flow dependent which included resources with specific well established flow requirements and non flow dependent. Potentially flow dependent resources from the draft list were assigned to either flow dependent or non-flow dependent categories.

The non-flow dependent IPUOCR are discussed below but are not expected to be addressed further in this study. The flow dependent resources are also discussed below along with proposed methods of assessment to be used to establish a protective instream flow (PISF) for each resource requiring an acceptable minimum flow. Resources requiring flows other than acceptable minimums (appropriate average or floods flows for example) are also discussed. A flowchart describing the screening process for flow dependent resources is provided in Figure 2-3.

2.8 Flow Dependence and Critical Flow Related Characteristics of IPUOCR Entities

The list of IPUOCR entities for the Lamprey River is extensive. However, many of these entities are not flow dependent. The matrix presented in Table 2-1 contains information from the preliminary list, literature review and the reconnaissance site visit. All IPUOCR entities were then classified as either flow dependent or non-flow dependent based on information known to the project team to date. Categories in the matrix include: the resource; the reason for inclusion; the local, regional and national importance of the resource; and the flow requirement of the resource including seasonality and duration, if known. Critical Flow categories of “High”, “Average”, and “Low” were assigned to IPUOCR if they were believed to be most sensitive to deviations from the Natural Flow Paradigm at

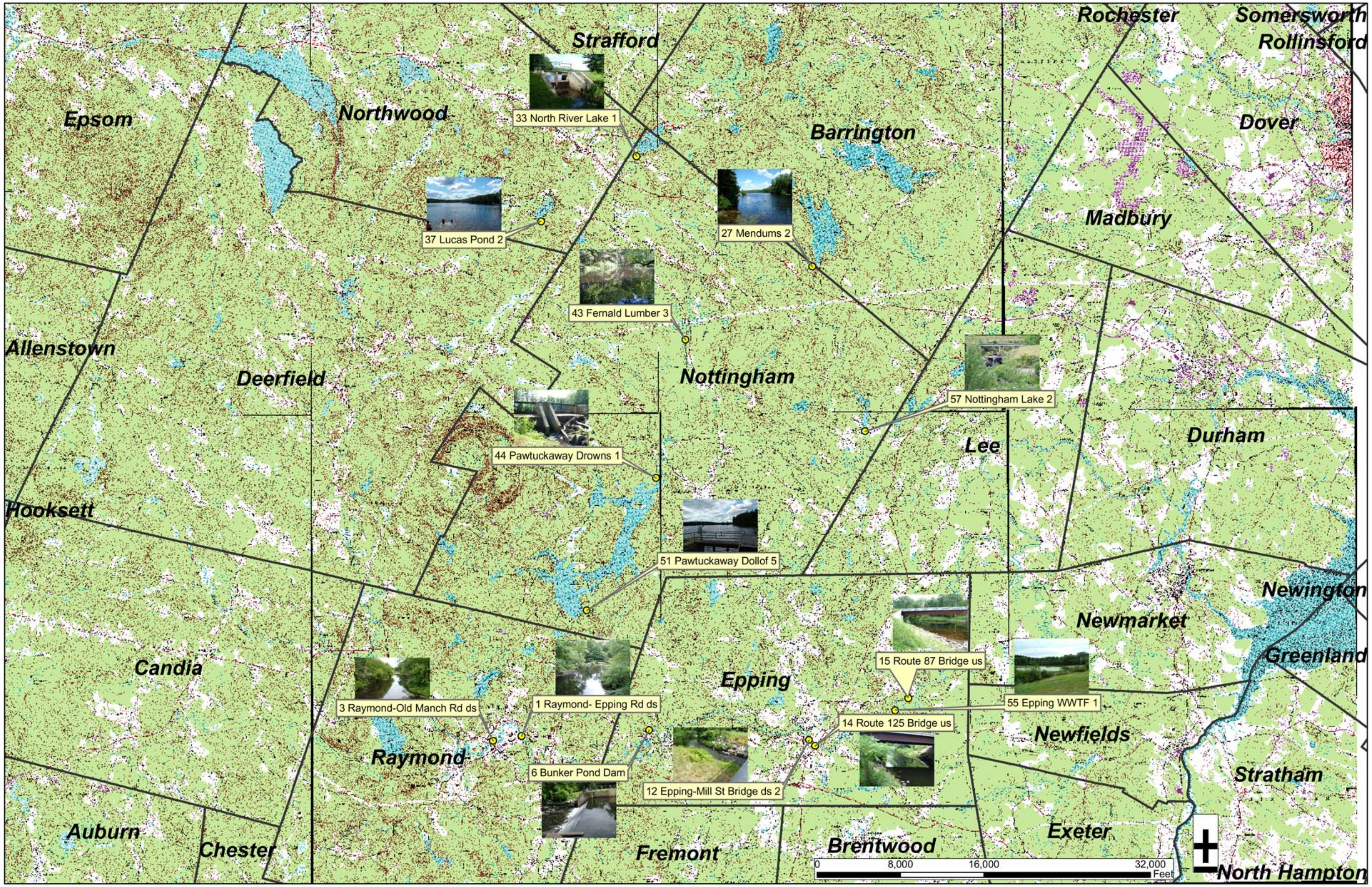


Figure 2-1. Locations of dams and other features in the Lamprey River watershed.

Figure 2-2. Locations of NWI Wetlands and Natural Heritage data.

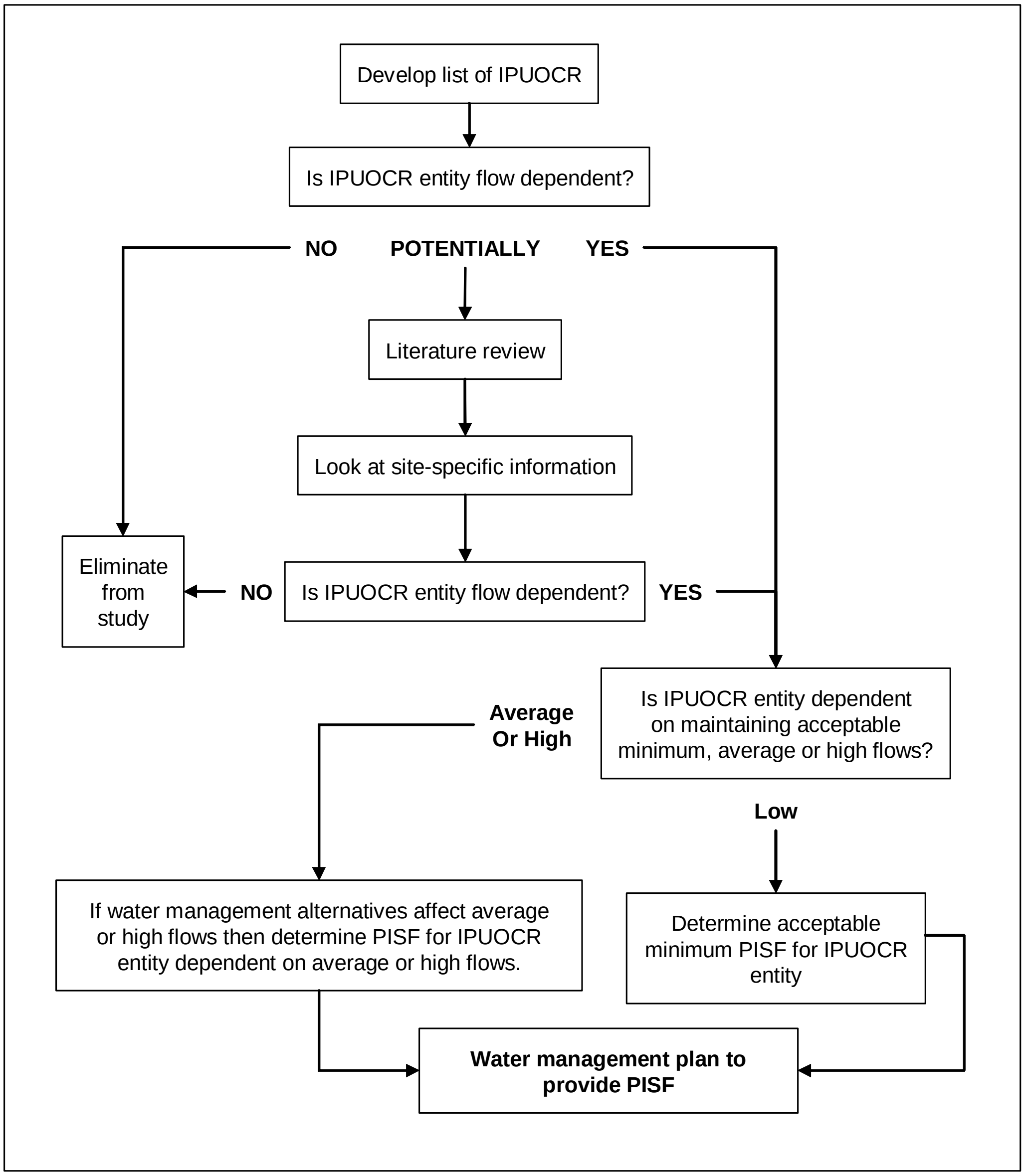


Figure 2-3. Flow chart of IPUOCR screening process.

Table 2-1. Matrix of IPUOCR's including flow dependence, reason for inclusion, critical seasons, life stages and method of assessment.

Category	Entity	Location	Flow Dep. Yes, No	Critical Flows High, Avg., Low	Critical Life Stage	Critical Season Sp Su F W	Method of Assessment
Recreation	Boating		Yes	High, Ave		Sp, F	Determine flow needs through observation and boater interviews
	Swimming		Yes			Su	Swimmer interviews
	Shoreland Recreation		No			All	
Storage	Wiswall Dam	Durham	No				
Fishing	Recreational		Yes	Low	Adults	All	MesoHABSIM
Conservation / Open Space			No				
Maintenance and Enhancement of Aquatic Fish and Life	Native Fish		Yes	All	All	All	MesoHABSIM
	Introduced Fish		Yes	All	All	All	MesoHABSIM
	Anadromous Fish		Yes	All	All	All	MesoHABSIM
	Mussels		Yes	All	All	All	MesoHABSIM
	Insects		Yes	All	All	All	MesoHABSIM
Fish and Wildlife Habitat	Fish Life Stage Habitats		Yes	All	All	All	MesoHABSIM
	Lower Floodplain Forest		Yes	High, Avg.	All	Sp	Floodplain transect
	Higher Floodplain Forest		Yes	High	All	Sp	Floodplain transect
	Alluvial Red Maple Swamp		Yes	Avg, Low	All	Sp, Su	Floodplain transect
	Oxbow and Backwater shrub swamps, marshes, ponds		Yes	All	All	Su	Floodplain transect
	Floodplain Vernal Pool Species		Yes	High, Avg	Eggs, Larvae	Sp, Su	Floodplain transect
	Mesic-Wet High Energy Riverbank		Yes	All	All	Su	Floodplain transect
	River Rapids		Yes	All	All	Su	Floodplain transect

(continued)

Table 2-1. (Continued)

Category	Entity	Location	Flow Dep. Yes, No	Critical Flows High, Avg., Low	Critical Life Stage	Critical Season Sp Su F W	Method of Assessment
RTE Fish, Wildlife, Vegetation or Natural/Ecological Communities	Bridle Shiner		Yes	All	All	All	MesoHABSIM
	Banded Sunfish		Yes	All	All	All	MesoHABSIM
	Brook Trout		Yes	All	All	All	MesoHABSIM
	Redfin Pickerel		Yes	All	All	All	MesoHABSIM
	Swamp Darter		Yes	All	All	All	MesoHABSIM
	Brook Floater		Yes	All	All	All	MesoHABSIM
	Blanding's Turtle		Yes	Avg, Low	Juv, Adult	All	Floodplain transect
	Wood Turtle		Yes	Low, High	Juv, Adult	W, Su	Floodplain transect
	Spotted Turtle		Yes	Avg, Low	Juv, Adult	All	Floodplain transect
	Osprey	Newmarket Durham	Yes	Low, Avg	Nesting, Adult	Sp, Su	Floodplain transect
	Bald Eagle	Newmarket	Yes	High, Avg	All	W, Sp	MesoHABSIM
	Sedge Wren	Durham	Maybe	High, Avg	Nesting	Sp, Su	Floodplain transect
	Pied-billed Grebe	Patchy	Yes	High, Avg, Low	Nesting	Sp, Su	Floodplain transect
	Climbing Hempweed		Yes	Avg, High	All		Floodplain transect
	Small-crested Sedge		Yes		All		Floodplain transect
	Star Duckweed		Yes	Avg,	All	Sp, Su	Floodplain transect
	Sharp-flowered Mannagrass		Yes		All		Floodplain transect
	Water Marigold	Newmarket	Yes	High, Low	All	Sp, Su	Floodplain transect
	Small Beggars Tick		Yes		All		Floodplain transect
	Knotty Pondweed		Yes	Low	All	Sp	Floodplain transect
	Slender Blueflag		Yes		All		Floodplain transect
	Swamp White Oak Floodplain Forest		Yes	High	All	Sp	Floodplain transect
	Peregrine Falcon		No				
	Eastern hog-nosed Snake		No				
	Philadelphia Panic Grass		No				
	Northern Blazing Star		No				
	Blunt-lobed Woodsia		No				
	Missouri Rock Cress		No				
	Downy False Foxglove		No				

(continued)

Table 2-1. (Continued)

Category	Entity	Location	Flow Dep. Yes, No	Critical Flows High, Avg., Low	Critical Life Stage	Critical Season Sp Su F W	Method of Assessment
Water Quality Protection and Public Health			No				
Public Water Supply	Durham-UNH town withdrawl	Durham	No				
Pollution Abatement	Epping WWTF	Epping	No				
Aesthetic Beauty / Scenic			No				
Cultural			No				
Historical or Archaeological			No				
Community Significance			No				
Hydrological / Geological			No				
Agricultural			No				

high, average, or low flows during flow-dependent life stages or operations. Flow deviations could include change in frequency, timing, duration and/or magnitude. For example, hibernating wood turtles are potentially harmed by drops in winter flows, as exposure and freezing could occur, while changes in the magnitude and duration of high, low, or average flows (that exceed the Natural Flow Paradigm) could alter emergent wetland functions and species associations.

The specific locations of resources that are rare, threatened or endangered were reviewed to the extent they were available but they are not presented. Likewise infrastructure information (dams, POTWs, water supplies) that could be used in a destructive manner was reviewed but is not presented. The NHDES will make the ultimate decision on whether or not to publish these data. The matrix of IPUOCR entities provides essential information needed to screen candidate methods for the determination of protected instream flow. The IPUOCR entities were initially screened for flow dependence (Figure 2-3). If an IPUOCR entity was determined to be dependent on an acceptable minimum flow, a procedure to determine an acceptable minimum PISF is proposed (Section 3). If an IPUOCR entity was determined to be dependent on an acceptable average or high flow, an additional step will occur. First, the universe of potential and practical water management alternatives will be determined for the Lamprey. If any of these alternatives affect average or high flows, a PISF will be determined for those IPUOCR entities dependent on average or high flows.

3.0 DISCUSSION OF IPUOCR ENTITIES AND PISF METHODS

3.1 FLOW DEPENDENT IPUOCRS

This section includes all flow dependent IPUOCR entities of the Lamprey River under their IPUOCR classifications as presented in Table 2-1. The discussion includes information describing the IPUOCR entities followed by the proposed method for determining protected flows for each type classification. The flow needs for each IPUOCR will be determined as described below and compiled. This compilation will provide the basis for the target flow regime to be provided by alternatives considered in the water management plan.

3.1.1 Recreation

Boating: The entirety of the designated reach provides opportunities for recreational flatwater and whitewater canoeing and kayaking. The river section from the Epping town line to Wadleigh Falls is listed by the AMC River Guide (AMC 2002) as consisting of quickwater with areas of Class II ledge. The river section from Wadleigh Falls to the Newmarket town line is listed by the AMC as consisting of flatwater, quickwater and Class I and III whitewater. The Packer’s Falls area is rated as a Class III run during the spring season and as a Class II run well into the summer. The above two sections of the designated reach are listed as passable during high to medium water during the spring and summer seasons. The project team did navigate by boat, the majority of the designated reach (excluding the Wiswall to Packer’s Falls section) on August 25 and 26. Flow during this time period was 18 to 23 cfs at the USGS Packer’s Falls gage, which is considered low.

Boating flows will be evaluated qualitatively through a combination of the observations of the field teams and interviews of boaters on the river during various river stages. These stages will include low summer flows and high spring flows. The team will coordinate with local paddling groups to develop a consistent interview format and to target appropriate time and flow windows for both kayakers and canoeists. If any water management alternatives considered in the water management plan include substantial changes in average or peak flows, this IPUOCR entity may need to be evaluated more quantitatively.

Swimming: Opportunities for swimming are available throughout the designated reach. There are four official beaches located within the designated reach in the town of Lee; Wellington campground, Ferndale Acres, Wadleigh Falls Campground and Glenmere Village Association. In addition to the official beaches, areas frequented by swimmers include the areas around Wadleigh Falls, Wiswall Dam, and Packer's Falls, along with numerous private residences throughout the reach. Much of the swimming conducted in the river occurs in impounded sections that are relatively insensitive to flow. During high flow periods, swimming in the fastwater, rapids, and falls sections of the river is considered ill-advised and dangerous. Swimmers will be interviewed as they are encountered on the river. Swimming will be evaluated quantitatively. If any water management alternatives considered in the water management plan include substantial changes in flows or water levels that may impact swimming, the IPUOCR entity may need to be evaluated more quantitatively.

3.1.2 Fishing

The majority of the fishing in the river is for stocked trout. The Lamprey River is regularly scheduled for stocking, and its stocking schedule can be found on the New Hampshire Fish and Game website. The species stocked in the river for 2004 were brown trout, Eastern brook trout and rainbow trout (see Table 3-1). The Lamprey River is a popular river for recreational fishing, as it is easily accessible, and provides a variety of habitats. Popular areas for fishing in Durham include the ¾ mile stretch between Wiswall Dam and Packer's Falls, and in Lee, the stretch between the North and Little Rivers and the areas around the Cartland Road / Little River Bridge and the Lee Hook Road / Lamprey River Bridge.

Table 3-1. Fish Stocked in Lamprey River in 2004.

Total Fish Stocked in Lamprey River - 2004				
Town	**Species**	**Age of Fish**	**# of Fish**	**Lbs. of Fish**
Deerfield	BT	1+Yr	560	108
Deerfield	EBT	1+Yr	1,625	665
Deerfield	RT	1+Yr	488	405
Durham	BT	1+Yr	540	121
Durham	EBT	1+Yr	1,400	575
Durham	RT	1+Yr	660	575
Epping	BT	1+Yr	950	193
Epping	EBT	1+Yr	350	144
Epping	RT	1+Yr	1,050	978
Lee	BT	1+Yr	1,010	200
Lee	EBT	1+Yr	1,330	546
Lee	RT	1+Yr	210	194
Raymond	BT	1+Yr	295	61
Raymond	EBT	1+Yr	1,050	439
Raymond	RT	1+Yr	550	470

BT – Brown Trout EBT – Eastern Brook Trout RT – Rainbow Trout

3.1.3 Aquatic and Fish Life Maintenance and Enhancement

Resident Native Fish Community

The New Hampshire Department of Environmental Services, through fish collections from various habitats using multiple sampling methods, has identified the resident fish community for the Lamprey River (2003). The results of these collections have been presented in the Lamprey River Baseline Fish Sampling Report (NHDES 2005; Table 3-2). Using the Lamprey Baseline Community (BFC) identified in the above report, we will select a set of native species for PISF modeling. We will use the existing habitat data base and literature to establish habitat selection criteria for each of these species. The fish collection data obtained during Lamprey River Baseline Fish Sampling will be used for future validation of habitat models. We will use fisheries data bases to develop a list of critical river ecosystem processes that influence habitat for migratory and specific life stages of the river fauna. The list will also include the annual periods when the fauna are particularly dependent on appropriate river flows. Subsequently, we will determine biological periods when migratory species and specific life stages of resident fauna are particularly dependent on appropriate flows. The timing and duration of these bio-periods is determined using a literature-based, life-history analysis of the biological needs of the resident target species identified in the Lamprey BFC, and the fluvial dependent, diadromous pulse species with potential to occur within the Lamprey River. Identifying critical bio-periods will allow us to recognize the corresponding flow regimes that are necessary to support the habitats required of these species during these times. This will be accomplished using a Lamprey River mean daily flow hydrograph (based on 71 years of record) to compare the identified bio-periods to the corresponding mean daily flows on the Lamprey River (Figure 3-1).

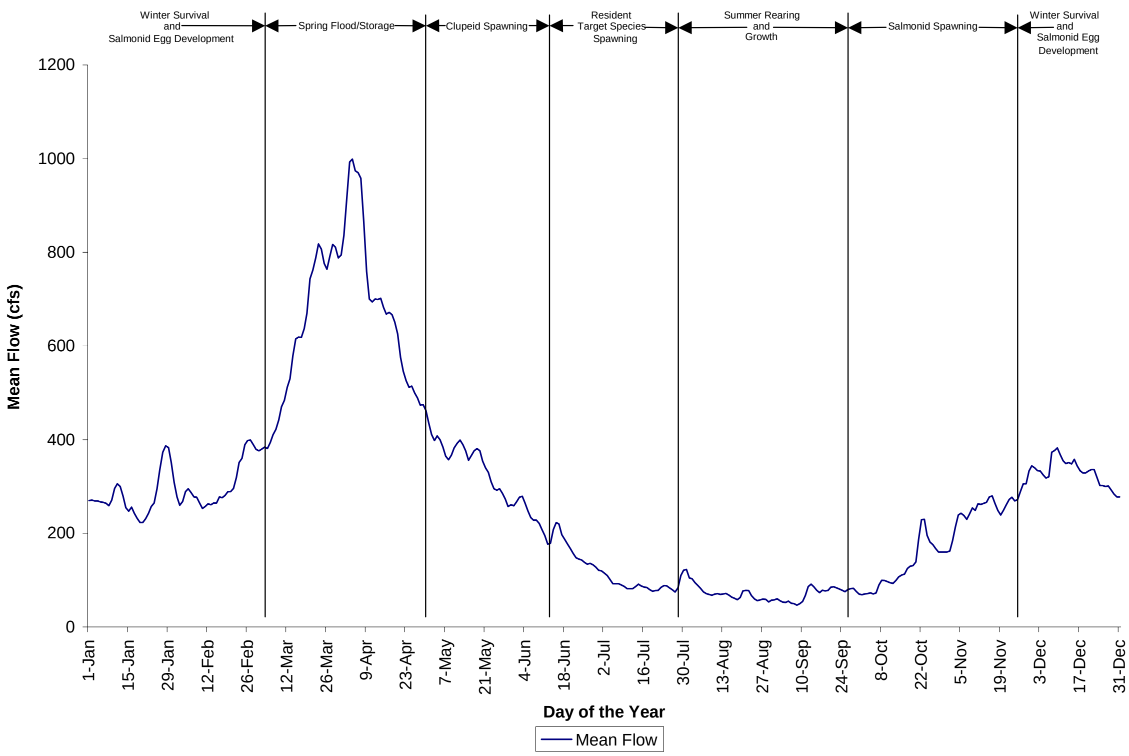


Figure 3-1. Bio-periods developed for the Lamprey River plotted over 71-year daily mean hydrograph.

Table 3-2. Summary of Lamprey Fish Assemblage (August 25-29, 2003) (NHDES 2005)

Fish Species		# of Individuals	Percent of Total Fish Captured	# of Stations Found (n=43)	% of Stations Found
Common shiner	FD)*	2140	33.9%	17	40%
Redbr east sunfish	(MHG)	948	15.0%	24	56%
Fallfish	RFS)	767	12.2%	24	56%
Pumpkinseed	(MHG)	377	6.0%	30	70%
Bluegill	(MHG)	358	5.7%	9	21%
Common white sucker	(FD)	324	5.1%	29	67%
American Eel	(MHG)	288	4.6%	26	60%
Longnose dace	(RFS)	287	4.6%	8	19%
Golden shiner	(MHG)	239	3.8%	17	40%
Smallmouth bass	(MHG)	128	2.0%	23	53%
Largemouth bass	(MHG)	95	1.51%	20	47%
Yellow perch	(MHG)	77	1.22%	18	42%
Bridle shiner	(MHG)	54	0.86%	5	12%
Yellow bullhead	(MHG)	51	0.81%	15	35%
Eastern chain pickerel	(MHG)	38	0.60%	17	40%
Creek chubsucker	(FS)	22	0.35%	10	23%
Alewife	(MHG)	21	0.33%	4	9%
Blacknose dace	(FS)	19	0.30%	2	5%
Black crappie	(MHG)	18	0.29%	3	7%
Rock bass	(MHG)	18	0.29%	1	2%
Atlantic Salmon	(FD)	13	0.21%	4	9%
Brown bullhead	(MHG)	11	0.17%	6	14%
Redfin pickerel	(MHG)	6	0.10%	4	9%
Brown trout	(FD)	3	0.048%	2	5%
Blueback herring	(FD)	2	0.032%	2	5%
Rainbow trout	(FD)	1	0.016%	1	2%
	Sum	**6305**	**100%**		

* Key to Habitat Classifications: FD=Fluvial Dependant; MHG=Macrohabitat Generalist; RFS=Regional Fluvial Specialist

Further, we will develop a list of fisheries management goals based on local, state, and federal management stakeholder values. Analyzing these goals and the key ecosystem processes driving the shape of the fish community, we will identify manageable components of the flow regime critical to achieving these goals and supporting the Lamprey BFC. The purpose is to “push” the river community towards desirable states to meet user goals and the biological needs of the LBFC. An important by-product of this process will be the identification of conflicting or incompatible user goals and gaps in management planning for the river ecosystem.

We will then develop a Reference Fish Community (RFC) based on the fish collection data obtained from the Lamprey River Baseline Fish Sampling and additional historical fisheries information. The RFC will modify Lamprey BFC for species that are presently either extirpated or under-represented (e.g., anadromous fish species) in the river and will represent a fish community that may have existed historically. The modifications of this RFC will be determined with help of state and federal fisheries experts who will estimate the ranks of under-represented species in the fish community. The ranks will be entered into the model to compute the expected abundances associated with ranks. The RFC will create the basis for the determination of habitat structure necessary to support the native fish fauna. This will then allow for a comparison of the existing habitat structure to the one needed to support the native fauna of the RFC. It will also predict the capability of the existing habitat structure to support the potential fauna of the RFC.

Native Fish Species

Species present in the designated reach of the Lamprey River include alewife, American eel, American shad, Atlantic salmon, banded sunfish, blacknose dace, blueback herring, bridle shiner, brook trout, brown bullhead, common shiner, common white sucker, creek chubsucker, eastern chain pickerel, fallfish, golden shiner, longnose dace, pumpkinseed, redbreast sunfish, redfin pickerel, sea lamprey, swamp darter, yellow perch, white perch. (NHDES 2005).

Introduced Fish Species

Species present in the designated reach of the Lamprey River include bluegill, black crappie, brown trout, largemouth bass, rock bass, smallmouth bass, yellow bullhead, and rainbow trout. Although these species are not native, they have been introduced and are part of the aquatic community (NHDES 2005). Rainbow and brown trout are currently stocked by the state of NH (Table 3-1).

3.1.4 Fish and Wildlife Habitat

Fish use habitat for spawning, feeding, nursing grounds, migration, and shelter, but most single habitats do not meet all of the needs of a fish. Fish change habitats with changes in life history stage, seasonal and geographic distributions, abundance, and interactions with other species. The type of habitat, as well as its characteristics and functions, are important to a diversity of fish species, and their changing life history needs. Descriptions of fish species, their characteristics, and habitats may be found in Appendix A.

Fish Life-stage Habitats

Freshwater portions of the Lamprey River, including the designated reach, provide spawning and rearing habitat for resident and diadromous fish. According to the Lamprey River Management Plan (January, 1995), “The presence of and potential for additional runs of river herring, American shad, and Atlantic salmon make (the Lamprey River) the state’s most significant river for all species of anadromous fish.” The river contains considerable amounts of suitable Atlantic salmon nursery habitat (gravelly, sloping bottoms, with cool, oxygenated water) and efforts to restore this species to the river are currently underway. The fish ladder at Macallen Dam in Newmarket passes alewife, blueback herring, American shad, sea lamprey, and American eels. This allows diadromous fish access to existing habitat from Great Bay upstream to Wiswall Dam. Potential habitat exists above Wiswall Dam pending the construction of a fish passage facility. Bathymetric studies of the geologic formations at Wiswall Dam reveal a low incline rock and ledge structure (USACOE 2005). Therefore it is believed that all of the diadromous fish species mentioned above (alewife, blueback herring, American shad, sea lamprey, Atlantic salmon, and American eel) had the potential to access spawning habitat at least as far upstream as Wadleigh Falls prior to the construction of the Wiswall Dam at this site (Patterson 2005). As a result of this belief, and in an effort to restore access to former spawning habitat for these fish, plans are currently underway to build a nature-like, bypass channel fishway (NHFG 2005).

Macroinvertebrates

Many macroinvertebrates such as freshwater mussels, mayflies (Ephemeroptera), stoneflies (Plecoptera), caddisflies (Trichoptera) (EPT Taxa) and Odonates (dragonflies and damselflies) are dependent upon good water quality. Their presence can be an indicator of a healthy water body. As with most macroinvertebrates, not much is presently known about their microhabitat needs. It is likely that habitat used by these animals can differ from fish habitat. Therefore, including macroinvertebrates in the investigation would help to represent a broader range of biodiversity for making instream flow recommendations. This is logical from a conservation viewpoint, because both of these groups contain state and federally listed endangered species. Efforts to conserve habitat for common species may generally result in protection for imperiled species. For reference we have summarized the key biological information about freshwater mussels and dragon/damselflies and included it in Appendix A.

Mussels

The freshwater mussel (Bivalvia: Unionidae) assemblage in North America is one of the most diverse known, and also one of the most imperiled (Vaughn and Hakenkamp 2001; Strayer et al. 2004). Essentially sedentary or slow-moving animals, the river species are particularly vulnerable to fluctuations in water level and current. Although many features of the watershed landscape have been shown to affect the composition of mussel communities (Arbuckle and Downing 2002), impoundment of rivers and the resultant effects on flow regime and host fish species are considered the primary factors in the decline of many North American freshwater mussel communities (Vaughn and Taylor 1999; Parmalee and Polhemus 2004; McGregor and Garner 2004). Flow stability and substrate composition determine where mussels are found in a water body (McRae et al. 2004), and patchiness in distribution may be due to the use of flow refuges (Strayer 1999). Flow velocities that are too high can negatively affect mussels by causing reduced juvenile recruitment (Hardison and Layzer 2001). Conversely, flow velocities that are too low can result in sedimentation, changing the substrate type and making it unsuitable for a given mussel species. Flow management is an important factor in maintaining a healthy invertebrate community in riverine systems (Brunke et al. 2001).

Mussels are important in bodies of water as they maintain clean water by filtering algae and plankton, and are a source of food for many species of wildlife such as raccoons and muskrats. Seven species of mussels have been reported from the Lamprey River, the brook floater, triangle floater, creeper, Eastern lampmussel, Eastern floater, Eastern elliptio, and alewife floater (Wicklow 2005). Several additional species may be present, including the Eastern pearlshell, Eastern pondmussel, tidewater mucket, and yellow lampmussel.

The life cycle of mussels starts with the release of sperm into the water by a male mussel, which a female mussel collects when siphoning water for food. The sperm is retained upon her gills, where her eggs are fertilized and develop in a few weeks. The next generation of mussels emerges after this time-period as glochidia, the larvae of mussels. Fish play a host, as the glochidia attach to the gills of specific fish species. Some of the identified hosts include tesselated darters, blacknose dace, golden shiner, longnose dace, margined madtom, pumpkinseed, slimy sculpin and yellow perch. These host species of fish are attracted to the area through a chemical emission, or lure, which the female mussel produces. Using the host fish as a means of dispersal, the glochidia are capable of reaching new locations in which they can colonize populations. These mussel larvae disengage from the host fish after a period of time, and if they relocate onto suitable substrate where local water velocities and flow regime of the river are suitable, the immature mussel will develop, and continue the life cycle.

Most freshwater mussels live burrowed in sand and gravel substrates, often occurring in the shallows of rivers and streams. Many species prefer a habitat that offers highly oxygenated water and moderate current. Only a few species have adapted to life in reservoirs, lakes or pools (lacustrine zones). Most freshwater mussels are dependent upon fluvial conditions and have an important role in river ecology. Factors such as water pollution, siltation, and impoundments have been known to cause declines in mussel populations. Well-established, diverse mussel colonies generally indicate a healthy aquatic environment.

Insects

There are a variety of insects that are dependant upon river systems for habitat and breeding grounds. In this study, effort will be focused on dragonflies and damselflies (order Odonata). Other taxa will be archived for future evaluation.

Odonates are good indicators of water quality and easily identifiable by their shed exoskeletons or adult forms. If river habitat is impacted by sedimentation or an increase or decrease in stream flow, these insects are affected. The flow needs of these macroinvertebrates vary throughout the season, as they emerge from rivers from the spring to early fall (Lenz 1997).

As of January 2003 there were 108 species of dragonflies and 44 species of damselflies reported in the State of New Hampshire (NH Odonates Club 2004). Many species of dragonflies and damselflies have been recorded throughout Strafford County, and within the Lamprey River watershed, but the only dragonfly species listed as endangered is the Ringed Boghaunter (*Williamsonia linteri*). This species requires acidic fen or sphagnum moss bog habitats that have been identified within the Lamprey River watershed. Such bog habitat exists at Durham Point Sedge Meadow Preserve, Durham, that currently supports ringed boghaunters (TNC 2004). Other bog habitats, suitable for ringed boghaunters, exist within the watershed in the Nottingham region and at Spruce Hole Bog, Durham. In general, Odonate larvae occur around most types of fresh water, but are uncommon in fast moving sections of streams. Both dragonflies and damselflies seem to thrive near sluggish waters. As a family, Odonates require a diversity of aquatic substrates upon which their eggs are laid. Several characteristics of these organisms make them useful indicators of water quality: many are sensitive to physical and chemical changes in their habitat, many live in the water for periods exceeding one year, and, they cannot easily escape pollution as some fish can. Odonata are easily collected in many streams and rivers for research.

Proposed Assessment Methods for Instream Resources

Early efforts to protect instream flow values arose primarily in the context of water-use allocation in western streams, many of which were already over-appropriated (i.e., demand often exceeded supply). As a result, early stream flow protection measures focused on the *minimum flow* that allowed for *maximum use* while preserving some (often only one or a few) critical aspect(s) of the stream system deemed necessary for survival of aquatic biota. This was often judged by relationships between flow, water temperature, and indices of suitable habitat for a few "indicator" species or species of management interest. Advances in understanding of relationships between stream flow and the biophysical structure and function of lotic systems led to the realization that stream ecosystem integrity depends on more than just the maintenance of a single, persistent low minimum flow. The "natural flow paradigm" (Poff et al. 1997) has emerged as a widely accepted framework for describing the roles of stream flow in shaping ecological characteristics of streams and understanding the consequences of modifications to natural stream flow patterns by human activity.

The natural flow paradigm (NFP) recognizes the importance of considering stream flow in terms of a *regime*. It is, a dynamic quantity that naturally varies over time in response to changes in many driving variables (precipitation, runoff, groundwater interactions, and evapotranspiration, to name a few) that occur over a broad range of spatial and temporal scales. Flow regimes can be described in terms of five general attributes that characterize temporal patterns and invoke conceptual linkages to other ecological variables. These include flow *magnitude*, *timing, frequency and duration and the rate of change. Magnitude* is used to distinguish between low, normal, and high flow conditions. The predictability of the *timing* of high and low flow events may select for or against various life history characteristics of resident biota. *Frequency* and *duration* interact to define disturbance intensity and the *rate of change* in flow conditions interacts with organism mobility and availability of refuge from intolerable physical conditions to further characterize the intensity and consequences of disturbance.

We propose to adopt the NFP as an organizing framework for developing PISF recommendations for the Lamprey River. Note that the NFP is not a "method". Rather, it is an over-arching philosophy that will be used to assess and prioritize efforts to understand the instream flow needs of various IPUOCR entities. It will also be used to devise new or select from existing methods needed to answer questions when placed in a water management framework. For example, initially the existing Lamprey River flow regime needs to be characterized and estimated to what extent it may already deviate from "natural" conditions. Statistical tools such as the Indicators of Hydrologic Alteration (Richter et al. 1996) and related indices like those used by Poff and Ward (1989) can be used to characterize patterns of stream flow variation across temporal scales. Stream ecologists are challenged to choose appropriate and relevant indices from the available suite of indices. Olden and Poff's (2003) comprehensive review of currently available hydrologic indices for characterizing streamflow regimes and their recommendation of non-redundant indices based on stream types will be used to guide index selection.

Preliminary results using six Indicators of Hydrologic Alteration (Richter et al. 1996) for the Lamprey River as compared to the Souhegan are shown in Table 3-3. The values for the three low flow IHA statistics (7-day low, 30-day low and low pulse duration) were compared with thresholds developed by the Massachusetts Water Resource Commission (WRC) for Massachusetts basins (Abele 2004) and indicate the overall Basin Stress Index as high. The duration of high and low pulses in the Lamprey show a level of persistence indicative of flow regulation, water withdrawals or generally low contributions from groundwater. A comparison of historical streamflow data (1935-1966) to more recent flows (1967-1990) showed that, while the duration of flooding events has remained relatively the same over the period of interest, the duration of drought periods has increased in the Lamprey. This increase in conjunction with moderate to high IHA indicators shows that the Lamprey basin is highly stressed (altered flow regime). This is likely due to human pressures resulting in increased water demand during annual low flow periods.

Table 3-3. IHA statistics for the Lamprey and Souhegan Rivers for the period of 1934 to 1976

	Median statistics for 1934-1976			
IHA	**Lamprey**	**Stress[1]**	**Souhegan**	**Stress[1]**
7-day low flow (cfsm)	0.06	High	0.13	Medium
30-day low flow (cfsm)	0.10	High	0.18	Medium
Low pulse duration (days)	18.50	High	13.16	High
Overall basin stress index		**High**		**Medium**
7-day high flow (cfsm)	8.36		9.13	
30-day high flow (cfsm)	5.11		5.94	
High pulse duration (days)	12.40		9.88	

[1] MA Stress thresholds	*Low-Med*	*Med-High*
7-day low flow	0.22	0.09
30-day low flow	0.30	0.16
Low pulse duration	6.80	10.90

Due to geographic variation in IPUOCR entities and existing water use patterns, methods will likely be needed to estimate stream flow records for un-gauged locations of interest in the watershed (see Richter et al. 1998). There could well be a need to compare flow regime attributes to those of a nearby reference stream, or between two time periods that bracket a significant change in water use within the basin. Consequences of such deviations, or of projected future water use scenarios, would then be evaluated with other methods specific to the nature of each IPUOCR entity. These could be grouped into classes or habitat guilds, reducing the number of methods ultimately required to address all pertinent issues (examples of such methods are given later in this section).

It is important to recognize that adoption of the NFP as a conceptual framework does not mean that PISF studies will automatically result in recommendations to restore a “pristine” hydrograph to the Lamprey River. Total restoration of an unaltered hydrograph allows for no water usage at all. It is generally technically impossible (due to human-induced changes in watershed characteristics) and socially infeasible (due to human demands on flowing water resources). The challenge is in devising water management strategies (including PISF levels) that effectively balance human needs for water with those of the natural systems which provide the water and other forms of “natural capital”.

Flow needs required to support multiple IPUOCR entities very often will conflict. This raises issues of fairness and inter-generational equity among present and future stakeholders. The draft list of IPUOCR “types” includes a mix of both anthropocentric (human-oriented) and “natural” uses to be protected. The NFP leads one to conclude that the latter are best served by an unaltered flow regime. The natural hydrology is a major component of the habitat template within which native biota evolved. It is often mediated through effects of stream flow on channel geometry, habitat diversity, and the timing and intensity of disturbance from droughts and floods. Alternatively, human demands on water resources are often continuous or display spatiotemporal patterns that do not correspond to the "natural delivery schedule".

Thus, from a water management perspective, it is important to ask, "How far can flow regime deviate from natural pattern before a system degrades?" To answer this question, assessment methods must use appropriate indicator variables that link flow regime alteration to changes in the biophysical properties of stream systems and their watersheds. It is unlikely that evaluation methods for this study will incorporate direct study of systems other than the Lamprey. However, comparative information is available from watershed assessments for other New England rivers, instream flow studies, ecological profiles associated with hydropower projects, and monitoring reports associated with other water resource development projects. Such analogs will contribute to the credibility of PISF recommendations by providing much-needed perspectives from which to judge the consequences of departures from natural flow patterns in the Lamprey River.

Even if much redundancy exists in the flow needs among IPUOCR entities, the set of issues to be considered remains diverse enough that no single methodology is likely to address all relevant questions. However, the IPUOCR entities can broadly be divided into those having natural or anthropocentric origins, and then further into sub-sets. Natural use categories for the Lamprey River have been identified by DES. They include wildlife, conservation, maintenance, and enhancement of aquatic and fish life, fish and wildlife habitat, and aquatic life and wildlife uses designated under the federal Clean Water Act. Natural outstanding characteristics and resources requiring protection are categorized as wildlife, natural, hydrological, geological, environmental, and ecological. Some IPUOCR entities, including fishing, fisheries, protection of water quality and public health, pollution abatement, aesthetic beauty, scenic resources, scientific resources, and consumption of fish and shellfish, are defined in ways that blur the distinction between natural and anthropocentric uses. In fact the flow needed may vary broadly across IPUOCR categories. Finally, IPUOCR definitions for navigation, recreation and recreational resources, water storage, cultural and archaeological resources, significance of community resources, agriculture, and hydroelectric energy production are clearly anthropocentric. Natural and anthropocentric resources can vary widely with respect to their dependence on the natural flow regime. However, such dependence, as well as the impact of deviations, will often be similar among sub-sets. This suggests that methodological approaches for one entity will usually be applicable or contribute to understanding of the flows needed to protect several.

Nevertheless, all IPUOCRs are related to the same entity, a running water ecosystem. Application of the PISF setting approach that balances anthropocentric water uses against maintenance of ecological integrity, as a measure of ecosystem sustainability, should address the objectives of the majority of uses and users.

Because analyzing all components of the aquatic ecosystem would be an enormous and overwhelming task, we propose to focus on fish and freshwater mussels as a primary indicator of ecological integrity. Fish and mussels are the primary animals of widest interest to the public in the river, and freshwater mussels are the most likely invertebrate group to be rare or endangered. Thus both are an important component of any PISF recommendation.

Literature Consulted for Lamprey River Fish Habitat and PISF

A number of literature sources were consulted to provide insight into methods for surveying the Lamprey River. Each of the papers consulted discusses methods of surveying flowing water, and eventually modeling its outcome. One source is a paper entitled "Overseas approaches to setting River Flow Objectives" by M. J. Dunbar et al. (1998) from the Environmental Agency and the Institute of Hydrology in the United Kingdom. Another source is "A Global Perspective on Environmental Flow Assessment: Emerging Trends in the Development and Application of Environmental Flow Methodologies for Rivers", by R. E. Tharme (2004) of the Freshwater Research Institute at the University of Cape Town, South Africa. A third source consulted is "Instream Flows for Riverine Resource Stewardship", by the Instream Flow Council (Annear et al. 2002). The fourth literature cited is "State-of-the-art in data sampling, modeling analysis and application of river habitat modeling," a Cost Action 626 Report written by Atle Harby et al. (2004). Each approach described by this literature was independent yet as described below, there is a definite theme that can be taken from their research, particularly concerning the assessment methods.

A report by the British Institute of Hydrology (Dunbar et al. 1998) identified three types of methods applied worldwide for the purpose of PISF determination:

"Look up" or standard-setting techniques, based upon simple hydrological indices such as percentage of the natural mean flow or an exceedance percentile on a natural flow duration curve were the most commonly applied. They aim to determine a minimum ecological discharge, sometimes with seasonal considerations, or other thresholds (desirable, optimum).

> Such methods require considerable resources to set up initially; but once developed require a relatively low level of resources per site. These standards can play an important monitoring and strategic role and provide interim objectives, where further investigation is justified. Good examples of look-up techniques include the Tennant and Texas methods, and the Basque method.

The other set of methods was called "Discussion-based approaches and hydrological analysis**".** These methods use "structured consideration of expert opinion".

> The methods are able to consider broad ecological functionality, plus species requirements at an intermediate level of detail. They may include elements such as hydraulic modeling, but the key assessment is undertaken at an expert panel workshop. This would be of particular use for setting more specific interim flow objectives, especially in the absence of clear species-related management targets, and ensuring effective targeting of further study.

The third category is "Biological response modeling", that refers to the Instream Flow Incremental Methodology (IFIM), and variations thereof.

> This type of approach is considered to be the most resource-intensive and defensible. Some countries have incorporated elements of the holistic approaches into their IFIM-equivalent framework. Another common approach is to incorporate multivariate classification of river sector types and their biotic communities.

The IFIM uses habitat simulation models as a basis for an integrative decision making process. It is frequently misunderstood and falsely equated with the Physical Habitat Simulation model (PHABSIM), which was the first modeling technique used for IFIM. The last twenty years have involved the application and further improvement of such models, along with heated discussion as to their validity (Gore and Nestler 1988). Since the creation of the original PHABSIM habitat modeling software (Bovee 1982) there have been a number of important developments. The most notable are the incorporation of new remote-sensing techniques (e.g., LIDAR topographic surveying) and spatial analysis technology (e.g., GIS) in support of computer simulations (Parasiewicz and Dunbar 2001).

Physical habitat models quantitatively describe the functional relationship between the physical environment and aquatic fauna. They are capable of predicting habitat conditions during river flows that were not measured which is useful based on the observation that aquatic biota respond to physical habitat patterns within a stream (Wright et al. 1993). Spatial distributions of physical attributes (e.g., depth or velocity) in combination with observation of biological response to their patterns, provide the basis for a predictive analysis of the consequences of ecosystem alteration (Milner et al. 1985; Stalnaker 1995).

Computer river simulation methods use high precision measurements of physical conditions to predict flow-based alteration of habitat, together with habitat suitability data for fish. The underlying approach of these river simulations is to describe these changes with a deterministic hydraulic model (statistical relationships between flow, water velocity, and depth) as described above. Originally, one-dimensional hydrodynamic models provided the only basis for habitat analysis, but these models assume that all river flow is in one direction (downstream and parallel). Recently two-dimensional models such as River2D can estimate hydraulic characteristics of the physical habitat and do not assume water flows only in one direction. This new capability more accurately describes habitat conditions because it can model complex flowing habitat such as river eddies.

The biological component of the PHABSIM model builds upon univariate response functions that individually consider the suitability of each hydraulic (depth, velocity) and geomorphological attribute. Subsequently, *a priori* selected algorithms (e.g., average) are applied to create composite suitability. In recent years, researchers have applied multivariate analyses such as logistic regression to more fully account for the interactive effects of habitat variables on fish distributions (Parasiewicz and Schmutz 1999, Guay et al. 2000). A recent comparative study conducted on the Quinebaug River demonstrated substantial discrepancies between the results of multivariate and univariate models which could lead to contrasting conclusions (Parasiewicz 2005; Parasiewicz and Walker in prep.).

PHABSIM was originally designed for applications related to individual water use facilities. It was not intended to be used as a standard settings tool for entire rivers and watersheds. Attempts to apply the technique as a broad planning tool have generated criticism (Williams 1996) because of violation of the principle of scale. Application of precision measurements on only a few selected locations (i.e. cross-sections) and drawing conclusions at the river or watershed scale generates large extrapolation errors stripping the technique of its defensibility. Instead, newer models such as River2D or watershed scale mapping techniques like MesoHABSIM (Parasiewicz 2001) are an improvement over site specific PHABSIM models in addressing community based systems scale and integrative assessment of ecological status.

MesoHABSIM (Parasiewicz 2001) is an experimental habitat assessment technique being developed in the northeastern United States that addresses the requirements of watershed-scale management of running waters. It is an improvement of PHABSIM developed in response to those concerns mentioned above, and to address needs of community-based, system-scale, integrative assessment of ecological status. MesoHABSIM modifies the data acquisition technique and analytical approach of earlier efforts by changing the scale of resolution from micro- to meso-scales. Hydro-morphological units (e.g., riffles, pools and runs) as well as associated hydrologic and cover characteristics are used to describe mesohabitats. When applying the MesoHABSIM survey approach, mesohabitats are mapped at different flows along extensive sections of a river. The suitability of each mesohabitat for a reference fish community is assessed using fishing surveys. These survey data are subsequently analyzed using multivariate statistics. The variation in cumulative area of suitable habitat is a measure of environmental quality associated with alterations in flow and channel structure (Figure 3-2).

River2D is freeware developed at the University of Alberta and taught by the U.S. Geological Survey (USGS). It has been applied to several watersheds in the west by the USGS. Normandeau Associates has applied it to sites on the Santee Cooper watershed in support of flows that meet navigation requirements and describe flow-habitat relationships for the fish community. River2D is scalable which means that it can be applied to sites or watersheds and modeling results can be examined on a transect level, micro-scale, or meso-scale. River2D models create digital terrain models and then use these topographic descriptions of the riverbed to solve complex hydraulic equations that estimate river stage, water velocity, flow direction, and water depth. For the biological modeling, traditional IFIM habitat suitability criteria can be used or site specific information can be brought into the model from multivariate assessments of site specific habitat use.

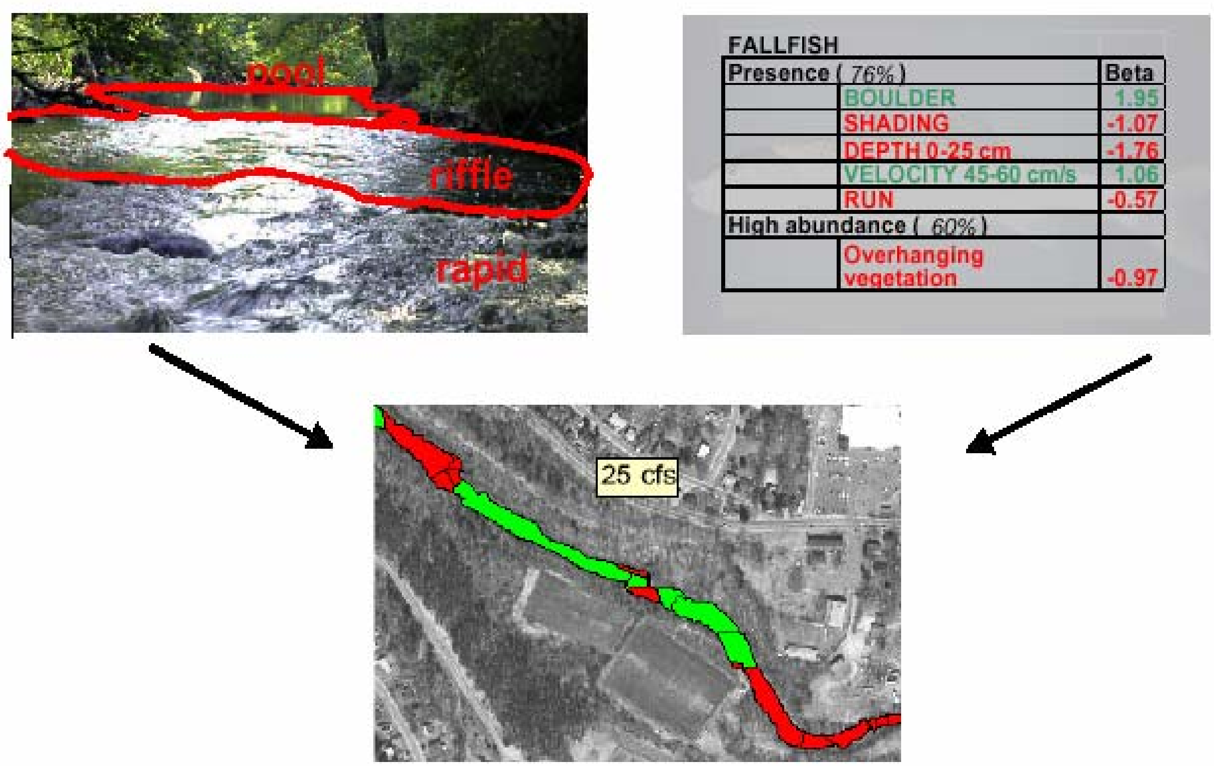


Figure 3-2. The habitat survey delineates hydromorphologic units and their physical attributes (top left). The fish survey is combined with this to identify key habitat attributes affecting fish (top right). The model calculates the probability of fish presence in each habitat and delineates areas of suitable and unsuitable habitat.

The other two sources reviewed within this study "A Global Perspective on Environmental Flow Assessment: Emerging Trends in the Development and Application of Environmental Flow Methodologies for Rivers", by Tharme and "Instream Flows for Riverine Resource Stewardship", by the Instream Flow Council provide a similar perspective. They both identify standard setting approaches and concur with the notion that these methods are adequate only for reconnaissance-level studies. Both sources also identify modeling techniques as effort intensive but precise techniques that are applicable for negotiations and detailed resource use planning. As a third category, Tharme (2004) identifies holistic methods that were similar to discussion of techniques in Dunbar et. al. (1998), but at higher level of sophistication. In Annear et. al (2002), the third category is named "Monitoring and Diagnostic Methods that Assess the Conditions". These methods however, are considered a tool of adaptive management.

"State-of-the-art in data sampling, modeling analysis and application of river habitat modeling," is a report which has been created by the European Aquatic Modeling Network (2005). The paper includes case studies from a variety of countries, and many examples of methods and equipment used to develop these surveys. The paper focused on techniques incorporating a wide scope of riverine habitat modeling that included modeling of other taxonomic groups as well as pollution monitoring. A key conclusion was that identification of appropriate habitat scales is a crucial element of instream habitat modeling. The authors emphasize the importance of a multi-scale approach to assure that analysis can be performed at the scales corresponding to the way biota utilize their environment. This allows for more comprehensive management. The report also states that frequent habitat assessment at some scales can be considered inefficient.

Habitat scales of assessment range from microhabitat to macrohabitat At a microhabitat scale, at the size of samples, it is unreasonable to assume that a sample taken from one location could yield the same results over the entire area, which the sample is meant to represent. Two areas with similar characteristics could contain entirely different species on the microhabitat scale. A macrohabitat scale assumes that the function and species diversity is determined by the stability of the system. The problem with this scale is a lack of the precision necessary for resource use decision-making.

> Mesohabitat scales are becoming more popular worldwide, and increasingly recognized as adequate scales for fish. Most commonly the size of mesohabitats corresponds with the size of hydro-morphologic units, such as entire pools, riffles, runs or backwaters. They create a "functional habitat" pattern, identifiable for the entire river and allow the creation of a basis for multi-scale assessment (Harby et al. 2004).

In addition to the desire for a unified method, most papers discussed the development of IFIM and PHABSIM, with MesoHABSIM becoming the latest method discussed at this time. The underlying philosophy of MesoHABSIM is the recognition that fauna react to the environment at different scales related to the size and mobility of the species (Nestler et al. in press) as well as the time of use. It defines the units of meso-scale (mesohabitats) as areas where an animal can be observed for a significant portion of their diurnal routine. It roughly corresponds with the concept of 'functional habitat' (Harper et al. 1995). The natural mobility of fish observation at the meso-scale is less affected by coincidence than at the micro-scale and can be expected to provide relatively meaningful clues about the animal's selection of living conditions (Hardy & Aadley 2001). As shown by several studies (Aadland 1993, Bain & Knight 1996, Lobb & Orth 1991), hydromorphologic units (HMU's) and mesohabitats commonly correspond in size and location, at least for adult resident fish. MesoHABSIM takes advantage of this non-coincidental relationship and defines HMU's as primary units of scale. Because of a coarser scale, HMU's are much more easily described and measured than micro-habitats and therefore allow for rapid surveys of large river sections, reducing the amount of extrapolation and associated errors.

Selected Methods for Fish Habitat Modeling

Our approach is to develop criteria for a flow regime that protects aquatic and riparian life within the designated reach and, by extension, throughout the watershed. Thorough understanding of ecological flow needs should create a basis for a Water Management Plan. For this project, methods need to be applied at two different scales. The flow requirements of the designated reach (DR) need to be assessed at the river scale and the WPA upstream of the designated reach needs to be analyzed at the watershed scale. The need for the second model is given not only by flow management opportunities upstream of the DR, but also by a necessity to protect this portion of the watershed from unintended damage, for example, by reduced flows. The primary approach is to classify the streams in the watershed based on their ecological status and potential vulnerability to change, as well as improvement opportunities that would reflect on the status of the fauna in the DR.

Because the developments in the WMA such as increased impervious area and higher flow fluctuations, could have a strong influence on conditions in the DR we may need to assess the conditions and potential impact sources upstream of the DR. If determined necessary we will apply generic techniques of impact assessment. The primary task will be to reconstruct natural flow regimes in delineated sub-watersheds. In order to accomplish this we will collect continuous and concurrent flow data at critical locations in each watershed. Subsequently we will compute Indices of Hydrological Alteration and identify coarse boundaries of suggested flow modification.

We will review available remote sensed data (satellite and aerial photographs) to study all of the sub-watersheds to the Lamprey River in an attempt to classify the land use and percent imperviousness. We will also investigate the possibility of isolating specific regions where changes in policy or introduction of mitigation could have a large influence on river quality.

Intensive analysis of the techniques applicable to the DR leads to the conclusion that meso-scale physical habitat simulations provide the most desirable base and the greatest potential for application on the Lamprey River. Physical habitat models link a small number of hydraulic (depth, velocity) and habitat variables (cover, substrate) to models of suitability for target biota (habitat suitability criteria) and are useful for establishing criteria when a specific site or sites have high importance to an IPUOCR.

We propose to apply this method to all free flowing sections of the Lamprey River using high resolution- multispectral-aerial photography as a primary tool of data collection. These data will be accompanied by ground-truthing surveys, which will help to calibrate and validate the image recognition software results for habitat delineation.

We propose to conduct mesohabitat mapping of the DR with high-resolution aerial photographs at four flows in the range between 0.15 cfsm and 2 cfsm as the primary approach to describing flow-related habitat changes. At each flight a 3,000 ft wide corridor along the river will be captured from an elevation of 4,000 ft providing a final horizontal resolution of 5 inches with 50% overlap (Figure 3-3).

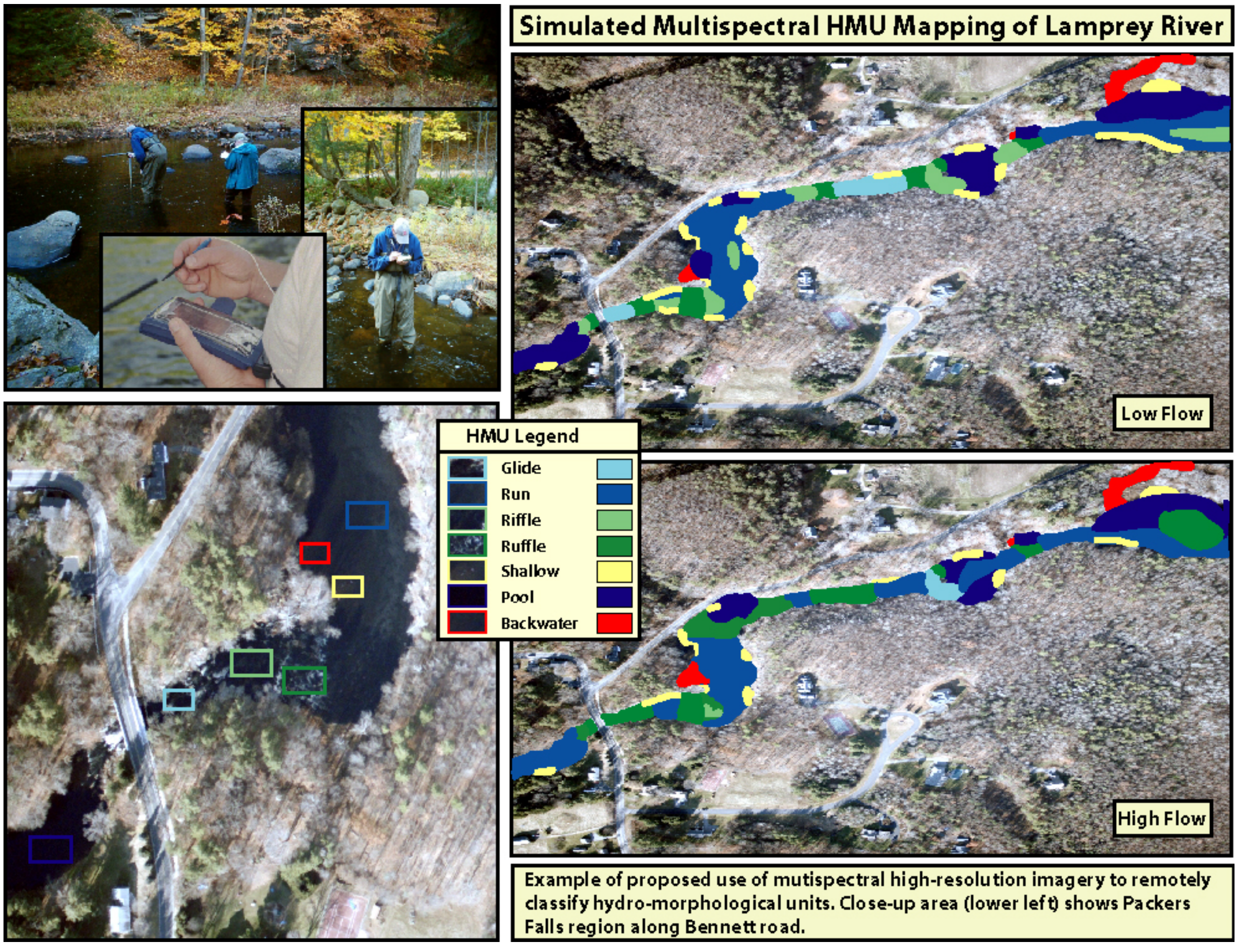


Figure 3-3. Schematic of mapping procedure planned for Lamprey River.

In order to increase our efficiency in conducting large scale field surveys of habitat characteristics, we will refine and employ software tools developed by Pal et. al (2001) for automating the classification of pixels in aerial imagery into categories relevant to habitat. They used a hierarchical, tree-structured Bayesian network probability model to integrate pixel color and intensity or texture (or wavelet) features in color aerial photography. This method was used in a software system for classifying pixels and larger regions into features relevant to landscape ecology and hydrologic modeling. In a related model (Pal et al, 2000) they used a Markov Random Field (MRF) to classify black and white aerial imagery. Figure 3-4 illustrates iterations of the MRF based algorithm.

We will adapt and build upon these approaches for automated recognition of habitat features and hydraulic patterns on the water surface.

Impoundments

In addition, we propose to perform a reconnaissance level survey of the impoundments. The purpose of the latter survey is to identify the species that utilize impoundment habitats and roughly estimate the value of this habitat for the aquatic community. This will be accomplished by utilizing SCUBA divers trained in the recognition of fish and freshwater mussel species who will also roughly map the underwater topography. Figure 3-5 shows an example of the result of this approach as it was applied

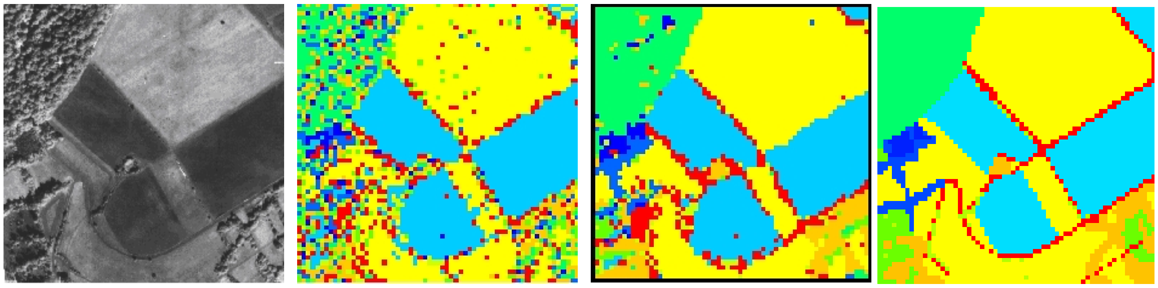


Figure 3-4. (left to right) 1. Black and white aerial imagery, 2. An initial segmentation, 3. Iterations of the algorithm 4. A "perfect" hand generated segmentation.

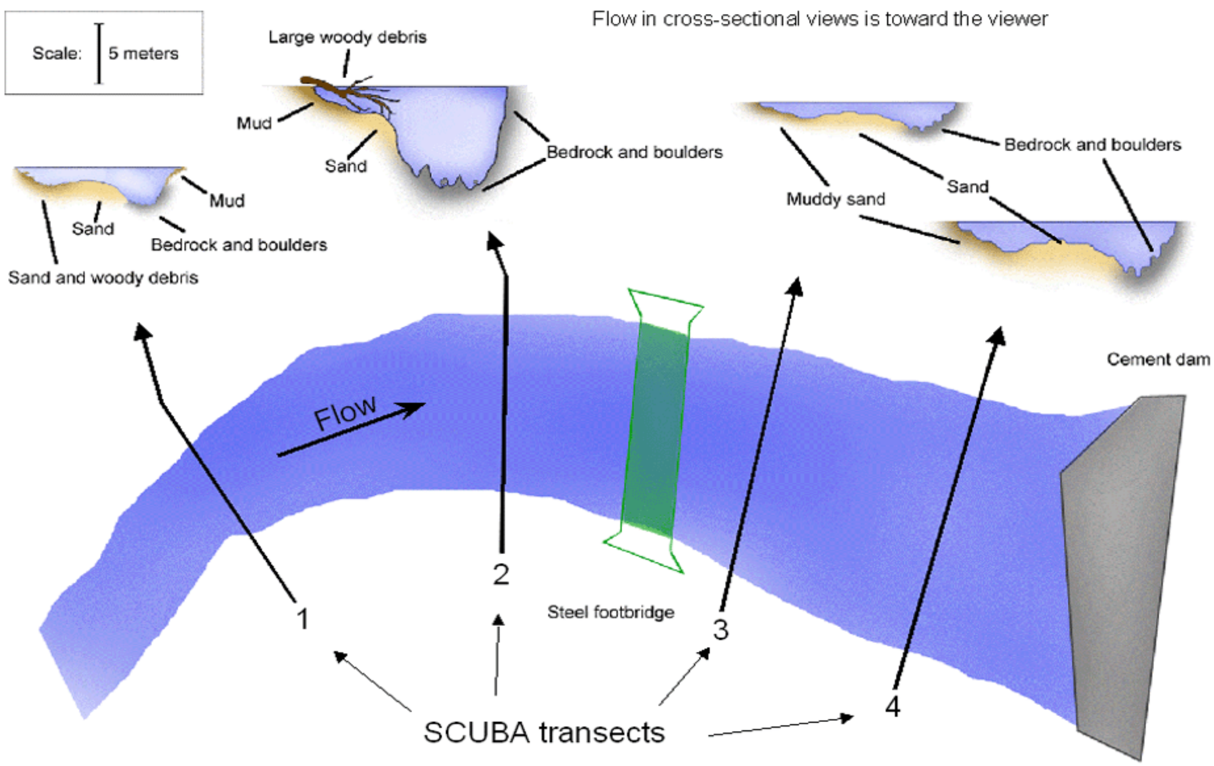


Figure 3-5. Results of scuba investigation of one impoundment on the Souhegan River.

to the Souhegan River. This information, while somewhat crude, provides a useful addition to the study that could not be obtained through wading or electrofishing surveys.

To create a habitat model, it is necessary to have two types of data. The characteristics of the stream and biological response functions, (habitat use criteria) allow us to evaluate hydro-morphology in terms of habitat suitably. Because of our experience working in the Northeast, we already have a well-developed habitat database on adult and early life stages of resident native fish for regional river systems (Souhegan River, Eightmile River, Pomperaug River, Fenton River, Stony Clove Creek) collected from instream surveys. These data allow for the development of habitat use criteria for the majority of fish species identified in this IPUOCR report. We propose to use these criteria as a basis for the evaluation of habitat quality for these species in the areas mapped with the MesoHABSIM technique.

We propose to select the resident species to be modeled based on BFC developed by the Department for Lamprey River. The species or species groups that have highest flow needs in particular season (eg. spawning salmon in the fall) will be selected as indicators for PISF needs and for habitat modeling. For species that are not included in our database, we will develop habitat selection criteria using literature values.

In general terms we will follow the approach developed during the Quinebaug and Souhegan River studies (Parasiewicz 2005) as described below.

The flow requirements of the fauna and of the flow regime itself vary through the course of a calendar year. When attempting to prescribe flows in a regulated river, it is necessary to take into consideration these flow and habitat fluctuations. To do this, we partitioned the calendar into bio-periods. These bio-periods reflect the special or critical times that a particular fauna or life stage may be particularly limited due to a lack in habitat.

The timing and duration of bio-periods are primarily based on upon species present and life history information found in the literature. Using the simulated hydrograph as a guide, we primarily lengthened or shortened the period by a small percentage in order to have the biological requirements coincide with a consistent flow pattern, which is often associated with a particular life history requirement such as high spring flows for spawning.

If biological data were unavailable or too sparse, we then developed periods based solely on consistent patterns (either relatively stable or relatively dynamic) in the simulated hydrograph. For example, the termination of the resident species' spawning period was adjusted slightly from general literature information to coincide with the inflection point of the receding limb of the hydrograph – the point where it is likely that the target fauna would cease spawning.

Spring/fall spawning and low flow summer survival/rearing and growth conditions were considered the primary biological periods of importance based on professional experience. Over-winter survival and the spring flood/storage periods are the other bio-periods and were evaluated solely by the simulated hydrograph since data for the targeted fauna are extremely sparse.

We selected the spawning periods of the top five target resident species and those of the two selected locally extirpated anadromous species (Atlantic salmon and American shad) from published literature. Most of these provided data from outside the immediate Quinebaug area. Bio-period values for a given species were established by exercising professional judgment if the data obtainable were not from the Quinebaug region. For example, spawning data for fallfish was obtained (in part) from New York and Virginia sources in order to estimate the period of spawning for Connecticut and Massachusetts. If the data were limited to these two sources, we "interpolated" between the ranges of dates and consulted the hydrograph to select a season for the Quinebaug region.

Using habitat rating curves developed from any method, in conjunction with flow time series for each river segment or IPUOCR site, we will create a time series of baseline habitat conditions which will be analyzed for flow levels critical to the protected use. We will apply continuous under threshold habitat duration curves (CUT-curves) using the technique described by Capra et al. (1995). The process is illustrated in Figure 3-6. Using this method we identify four habitat levels that correspond with different protection thresholds. These levels divide the flow regime characteristics along a gradient of potential impact and are named *extreme, rare, critical, and common*.

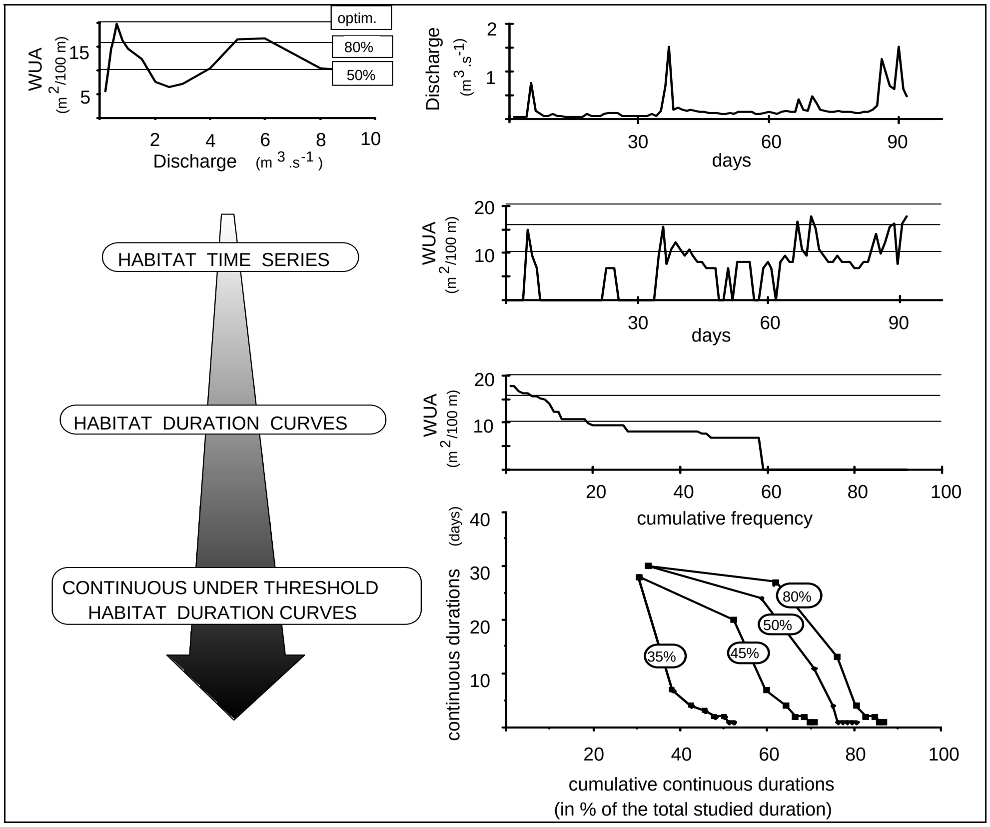


Figure 3-6. CUT curves from habitat time series (source: Capra et al., 1995)

Again we will build here upon the methodology developed during the Quinebaug River Study:

A set of CUT curves for a bio-period are generated by analyzing negative run-time length (i.e. continuous durations of under threshold) characteristics of habitat time series (habitographs). Habitographs are computed by applying flow/habitat-rating curves developed for restored river conditions to a given season's flow time series. The magnitude and duration of habitat run-length characteristics relative to a series of thresholds is plotted as habitat duration curves on one chart. Thresholds were initially selected on an iterative basis until we were able to refine our evaluation to target threshold "regions". These target threshold "regions" demonstrated characteristics where trends depicting common and uncommon occurrences could be discerned.

For the low-flow conditions, we identified four habitat levels that corresponded with different levels of thresholds following the theory of physical habitat templates (Poff and Ward 1990, Townsend and Hildrew 1994). These levels were named *extreme, rare, critical, and common*. To define the *extreme* (which is the lowest habitat level allowable), we selected the lowest non-zero habitat level that occurred in the pre-development daily streamflow time series. To define the other three levels, we interpreted the shape of the CUT curves and their location on the graph shown below as Figure 3-7.

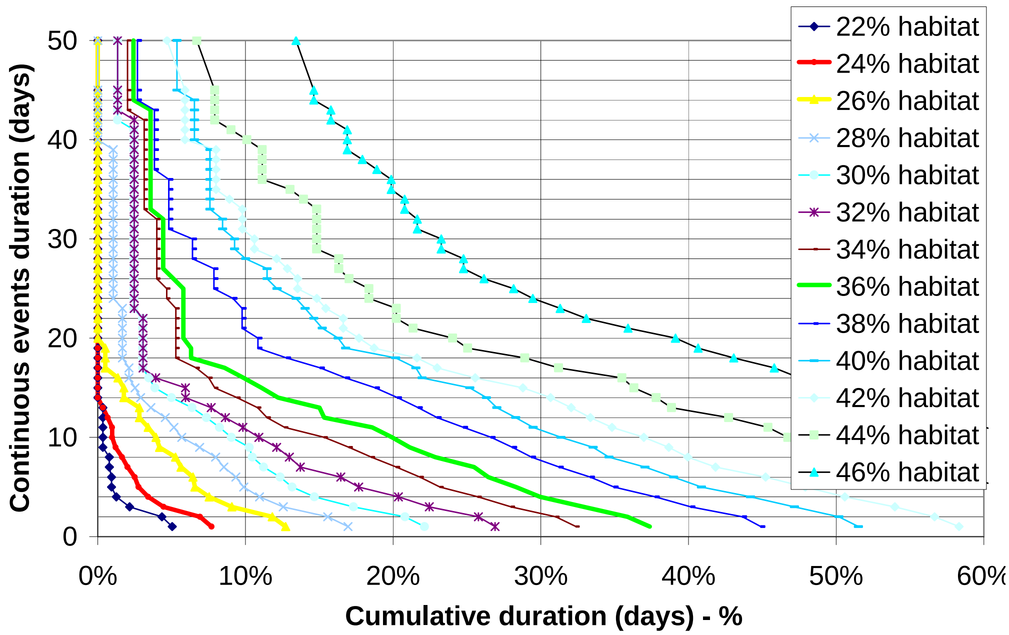


Figure 3-7. Continuous Under Threshold duration (CUT) curves representing percentages of available habitat area for adult resident fish in the Quinebaug River during the summer season.

In Figure 3-7, the selected increment between habitat levels is 2% of the channel's wetted area. The horizontal distance between the curves indicates the change in frequency of events associated with a habitat increase to the next level. The curve spacing increases constantly but in non-uniform increments, thereby displaying a sudden shift in frequency. We assume that thresholds are associated with such a significant increase of spacing between the CUT curves.

We observed that for *rare* levels, which are exceeded very frequently and over long periods of time, the curves are steep and located in the lower left-hand corner of the graph. The curve representing the highest level of this group of curves has been chosen as a *rare* habitat level. The first curve that stands out is identified as the *critical* (yellow curve) as it marks the lowest of events more common than *rare* (red curve). After exceeding the *critical* level, the lines begin to space out more. The next significant increase in the distances between the CUT-curves marks a first *common* (green curve) event.

For each of these thresholds, we also identified significant changes in the shape of the curves as to define the shortest common, longest common and catastrophic durations. We divided the duration of events into one of two categories: acute or catastrophic. The shortest common duration, the lowest inflection point on the CUT curve, is then used to determine the release pulse length. The longest common duration, the uppermost inflection point of the CUT curve, defined the maximum durations for which the habitat can fall under the threshold or duration between successive pulses as needed. The catastrophic length demarcates the duration that, if exceeded (e.g. for lack of water), would require additional mitigation actions in order to recover the fauna. In an operational sense, approaching catastrophic event duration should trigger an immediate dam pulse-release.

The result of this analysis will be recommendations for seasonal habitat regimes consisting of allowable habitat quantity together with duration and frequencies of flow events with habitat under specific thresholds. In addition, the amount of water necessary to fulfill the above criteria will be defined for every season. We will develop a concept for the application of these criteria by introducing dynamic flow management rules. This will include flows that trigger protective actions, allowable durations of these flows, together with duration and magnitude of protective flow pulses. For each flow scenario we will also analyze change in wetland habitats as well as potential impact on stream miles in the WMA upstream of DR. The above rules will be accompanied by boundary conditions protecting wetlands and upstream areas.

In subsequent steps, we will list river channel improvement opportunities within the WMA by identifying areas where such measures could be more easily applied than on private property (e.g. public parks). The potential of these measures can be analyzed by simulation of the gain in fish habitat. This step will assist in the evaluation of potential water management vs. restoration trade-off options in the water management plan. This may be particularly applicable where water use conflicts cannot easily be mitigated. The water management plan will build upon simulation results and determine how water can be allocated in order to satisfy the above flow recommendations.

Natural Communities and Wildlife Habitat

Many of the wetland, floodplain and river channel plant communities along the Lamprey River are flow-dependent habitats for a variety of flow dependent and non-flow dependent wildlife. Wetland types along the Lamprey River include forested floodplain, oxbow marshes, and shrub and forested swamps at the mouths of tributary streams and riparian margins. The plant community types associated with important wildlife habitats have been classified by the Natural Heritage Bureau, and are described below.

Lower Floodplain Forest

Lower floodplain forests are typically 3 to 5 feet above summer river levels and 1 to 2 feet above average spring high water. These forests probably flood annually during peak flood flows. Dominant tree canopy species include red maple (*Acer rubrum*), red oak (*Quercus rubra*), American elm (*Ulmus Americana*), black cherry (*Prunus serotina*), and shagbark hickory (*Carya ovata*). Musclewood (*Carpinus caroliniana*) is a common understory tree, and shrubs, including several species of viburnum may be common. The ground cover is a mixture of ferns, sedges and other forbs. Such forests were observed above Wadleigh Falls and in small, scattered locations below this. Silver maple (*Acer saccharinum*) may be found along the river occasionally in narrow bands or with other lower floodplain species. These trees are generally found about 1 to 2 feet below the other lower floodplain forests, and were most common below Packers Falls, particularly near Moat Island.

Higher Floodplain Forest

Higher floodplain forests, positioned approximately 1 to 3 feet higher than lower floodplain forests, generally flood in 5-100 year cycles. These forests are reminiscent of mesic mixed forests, often including hemlock (*Tsuga canadensis*), but also suppor many lower floodplain species. These forests are often present adjacent to the lower floodplains, either further back from the Lamprey River or on naturally higher banks along the river edge.

Alluvial Red Maple Swamp

Red maple swamps on organic soils may develop within old oxbows, meander scrolls or tributary basins protected from swift water and scour. These swamps are similar to other red maple swamps in basins not located in the floodplain of the Lamprey River, and are sometimes associated with emergent and shrub swamps.

Oxbow and Backwater Shrub Swamps, Marshes and Ponds

These open-canopy communities are vegetated with shrubs, emergent marsh plants or submersed and floating leaved plants, depending on depth. Often they are found in a mosaic pattern with other floodplain wetlands. They are always influenced by the flood regime of the river, though some may be hydrologically isolated at low water. Beaver dams or man-made dams retain water in some of these oxbows and backwaters. Notable backwater and oxbow marshes were observed above Wiswell Dam, below Packers Falls, and around Moat Island. Numerous small fish, painted turtles (*Chrysemys p. picta*), and green frogs (*Rana clamitans melanota*) were observed in these marshes. Changes in river water levels would affect primarily those wetlands with direct and unrestricted surface water connections to the river. The magnitude of the impact would depend, in part, on the elevation of the marsh relative to the river channel, the constriction of the surface water connection, and the frequency, regularity and duration of flow changes.

Floodplain Vernal Pool

Shaded oxbow ponds on the forested floodplain typically have sparse vegetation, but may have similar hydrology to open oxbow marshes and ponds. Some of these function as vernal pools, important breeding areas amphibians and invertebrates, and feeding areas for many wildlife species. Carroll (1994) noted several in the floodplain above Lee Hook Road.

Mesic-Wet High Energy Riverbank

This classification includes a variety of herbaceous plant associations in seasonally to semi-permanently flooded portions of the river channel. Species richness is often high, as plants may be emergent, amphibious or moist site species. The substrate may be very fine, or coarse, including alluvial sand or cobble bars and banks. An example is the alluvial bar just downstream of the Lee Hook Road in Newmarket. Common plants in this habitat type may include cardinal flower (*Lobelia cardinalis*), water purslane (*Ludwigia palustris*), sensitive fern (*Onoclea sensibilis*) and false nettle (*Boehmeria cylindrica*).

River Rapids

Plant communities adapted to semi-permanently to permanently flooded conditions at high energy sites are present at Wadleigh and Packers Falls and the rapids near Lee Hook Road. Riverweed (*Podostemum ceratophyllum*), white water crowfoot (*Ranunculus tricophyllus*) and knotty pondweed (*Potamogeton nodosus*) are plants typical of rapids in the Lamprey River as observed by Sperduto and Crow (1994) at several of these locations. Numerous other species of plants may appear as water levels drop through the growing season.

Wildlife Habitat

Several floodplain wetland complexes representing combinations of the above plant community types within the study area were noted by various investigators for their habitat value, including:

- An area just north of Glenmere Village, noted for excellent bird habitat; vernal pools; emergent, forested and shrub wetlands; beaver dams; musk, painted, snapping turtles and potentially other turtle species;
- The Tuttle Swamp, with several floodplain and wetland cover types, including an outstanding Swamp White Oak (*Quercus bicolor*) Floodplain Forest and a rare plant; and
- A floodplain/wetland complex east of Lee Hook Road with potentially critical habitat for turtles, waterfowl, beaver etc.

Habitats with a direct hydrological connection (groundwater or surface water) to the river at some time during the growing season are potentially susceptible to prolonged changes in flow. Prolonged flooding and/or prolonged low water during the growing season both alter plant communities and microhabitats for plants, fish and wildlife. Major changes in winter flows could expose wintering aquatic animals to ice, scour, desiccation or dislodgement.

Wildlife dependent on these floodplains and wetlands may also be flow dependent. Loss of water in critical microhabitats during critical life stages can result in freezing or desiccation of water dependent animals. Examples include breeding amphibians that require ponded water for several months for aquatic egg and larval stages and turtles overwintering and feeding in the river channel. Flow-dependent wildlife species observed informally from the Lamprey River corridor include spring peeper, gray treefrog, bullfrog, green frog, wood frog, northern leopard frog, pickerel frog, American toad, Jefferson, spotted, and northern two-lined salamanders; red-spotted newt; and six turtle species, including spotted, Blanding's, snapping, wood, painted, and musk.

Many other wildlife species may be indirectly flow dependent as they rely on flow-dependent food sources. Examples include American black duck, black-crowned night heron, kingfisher, northern water snake, and ribbon snake. Bats and semi-aquatic mammals, such as mink, muskrat, otter and beaver may are also indirectly flow dependent through dependence on aquatic food sources.

Changes in river water levels would affect primarily those wetlands with direct and unrestricted surface water connections to the river. The magnitude of the impact would depend, in part, on the elevation of the marsh relative to the river channel, the constriction of the surface water connection, and the frequency, regularity and duration of any flow changes.

Flow Requirement Assessment

Several methods for determining flow requirements for riparian and floodplain communities and their associated fauna were considered for this project, including the Floodplain Transect and Wetland Photogrammetry Models described in our proposal to NHDES for this project. During the IPUOCR field reconnaissance, significant tree canopy was observed over the edges of the Lamprey River, backwater and oxbow marshes, and adjacent floodplain. This cover would obscure ground and water surfaces in aerial photographs taken during the growing season (May to October), when the likelihood of low flows is greatest. Additionally, large portions of the riverbank are populated by coniferous trees which would obscure the riparian zone throughout the year. It was also apparent that some of the natural communities of interest appear in narrow zones that will be difficult to discern on the scale of aerial photos. For this reason, we intend to rely primarily on the information that can be collected through the Floodplain Transect Model, supplemented by aerial photographs collected as a part of the instream evaluation, where possible. At sites where air photointerpretation is possible, a comparison between aerial methods of evaluating cover and the transect method will be provided.

Floodplain Transect Model

Determination of minimum flow requirements for wetland, floodplain, and channel habitats and their associated flora and fauna will involve transect surveys across the river floodplain and channel, including selected backwater marshes, oxbows, vernal pools, etc. The expected change in plant community boundaries associated with water level changes at each topographic position is identified on the transect elevation model and transferred to a baseline cover type map developed from aerial photographs. For modeled flow scenarios the change in habitat suitability area will be calculated for a given segment of the river and extrapolated to other relevant reaches. The relative loss or gain of plant community types will serve as a measure of impact to the adapted flora and fauna. Where available, habitat suitability data will be integrated into the assessment. The initial steps involved with the Floodplain Transect Model are as follows:

- topographic survey of floodplain, wetland and adjacent river channel along transects, including the lowest point of connection with the river channel and deepest point of marsh;
- elevation of water recorded simultaneously in wetland and river at seasonal low flow (or as determined by historical data), average and high flows. An attempt will be made to coordinate these evaluations with the evaluation of aquatic habitat and fauna.
- Use of a stage-discharge relationship and topography at each transect to determine profiles of water levels along each cross section at representative flows.
- primary vegetation types (emergent, floating leaved or submergent) in the wetland plotted along the transects;
- estimation of minimum flow required to maintain low flow surface water elevations of:
    - 0 (sediment surface) for emergents,
    - 6 inches for floating-leaved;
    - 12 inches for submergents.

A cover type map showing the distribution of habitats in the floodplain of the selected reach around each transect will be prepared, based on aerial photos, and will be used to relate habitat changes associated with each transect to the entire river segment. This methodology will be applied at three or four sites in the designated reach. The number of necessary transects at each site will be determined in the field. These sites will be chosen to overlap with the range of flow dependent species wherever possible. Examples of the Floodplain Transect Model and type of output from this effort are presented in Figures 3-8 – 3-12.

Though the analyses of flow effects on IPUOCR's may focus on particular transect locations, the floodplain habitats discussed are part of an integrated and shifting mosaic, changed by river processes and beaver activity, with each habitat type important in the overall landscape for any number of wildlife species at a particular season or life stage. Many wildlife species likely to use floodplain habitats may also need adjacent undeveloped uplands or hydrologically independent wetlands to sustain their populations.

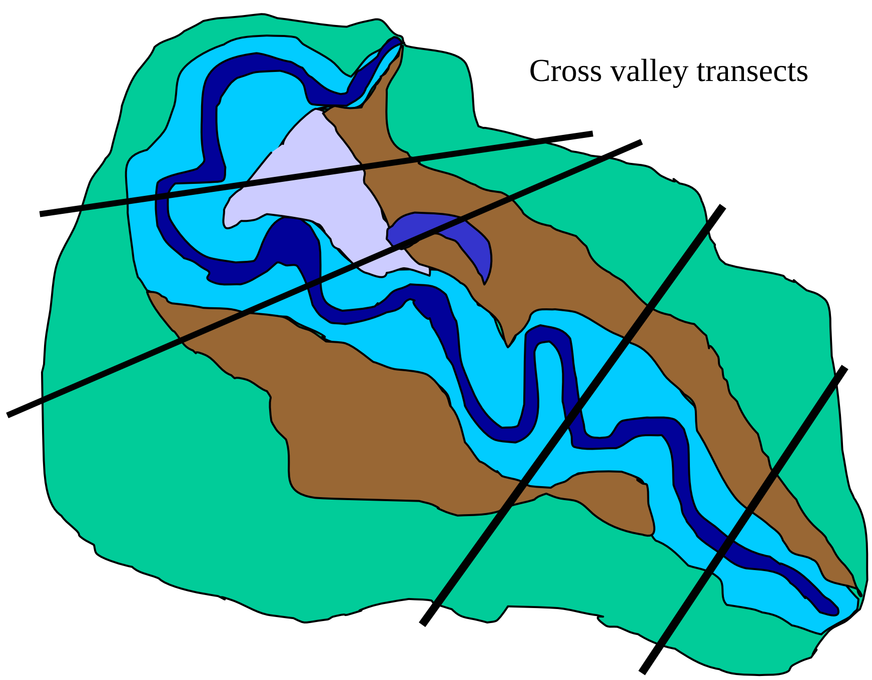
3.1.5 RTE: Fish, Wildlife, Vegetation or Natural/Ecological Communities

Fish

The New Hampshire Fish and Game Department's recent Wildlife Action Plan (NHFG 2005) was reviewed to identify fish species of "greatest conservation concern". Much of the information regarding the habitats uses of these fish within the state of New Hampshire was obtained from this plan. The species listed were then compared to field fish sampling records conducted by the NHFG and the NHDES (NHDES 2005) to determine those rare, threatened, and endangered or species of conservation concern currently or historically occurring within the designated study reach of the Lamprey River.

Diadromous Fish Species

The designated study reach currently provides spawning habitat for diadromous fish species. Plans to construct a natural bypass channel at Wiswall Dam, within the study area, would provide access to 43 additional river miles of potential spawning habitat for these fish (ACOE 2005). The New Hampshire Fish and Game Department considers the Lamprey River one of the most important rivers in the state of New Hampshire for all anadromous fish species, due to its current runs and potential to support future runs, according to the Lamprey River Management Plan (1996) (http://www.des.state.nh.us/rivers/plans/lamplan.htm). This assertion lends reason to consider the flow needs of the diadromous species within the designated study reach with high regard. The very nature of diadromy, requiring diadromous fish to migrate to and from stream habits to reproduce and successfully complete their life cycles (Gross 1987), make these fish especially dependent upon specific flow conditions during their respective annual migrations and spawning times (Zabel 2002).



Adapted from Scott Jackson, UMASS

Figure 3-8. Layout of transects.

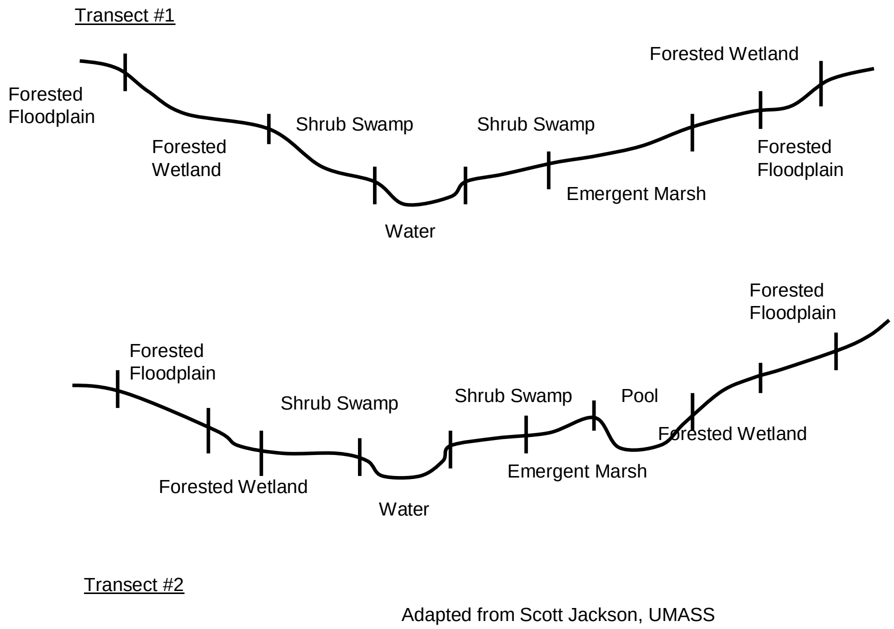


Figure 3-9. Transect habitat mapping.

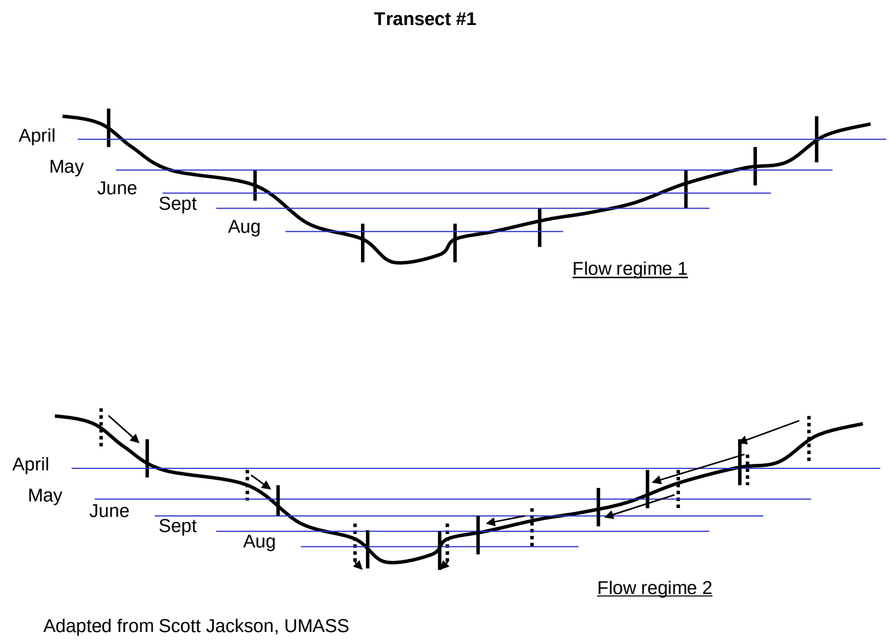


Figure 3-10. Habitat under different flows.

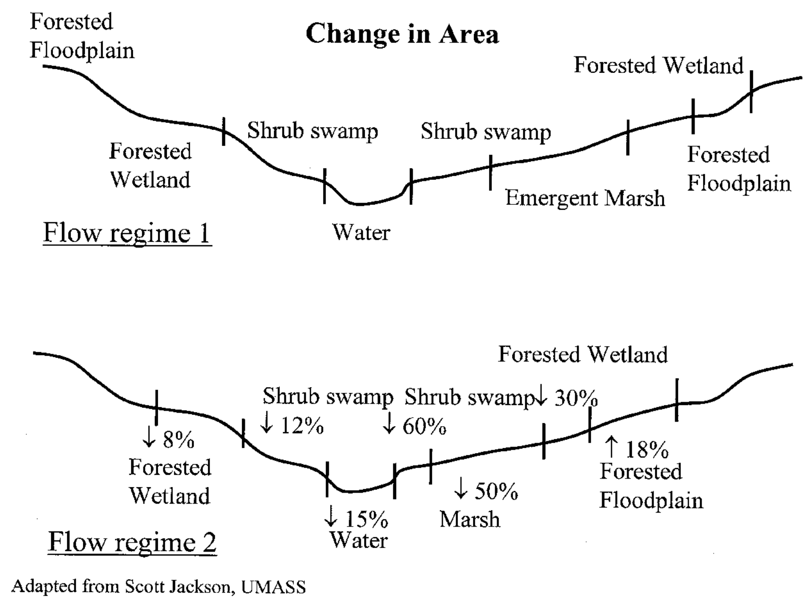


Figure 3-11. Relative change between flow regimes.

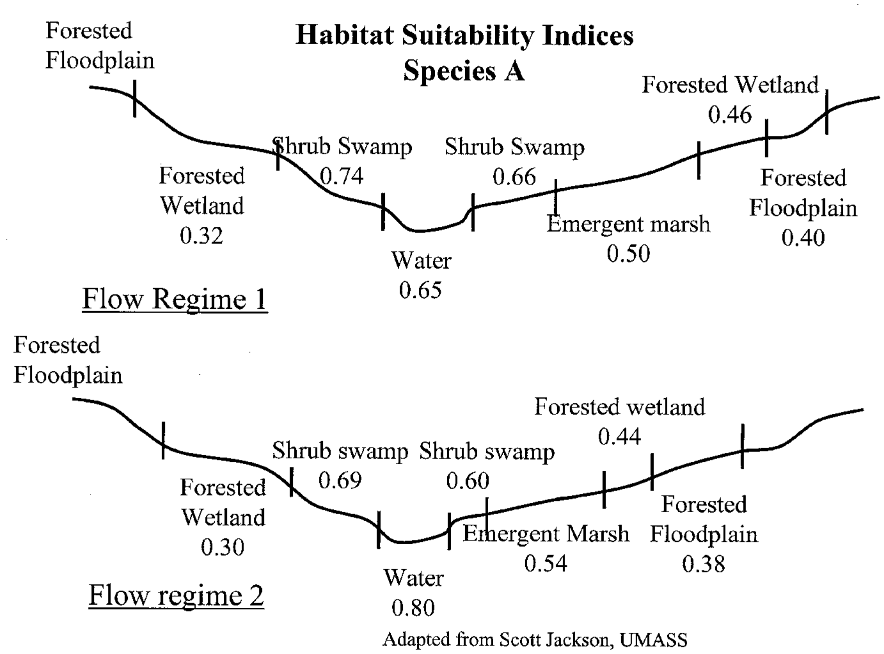


Figure 3-12. Habitat suitability under different flows.

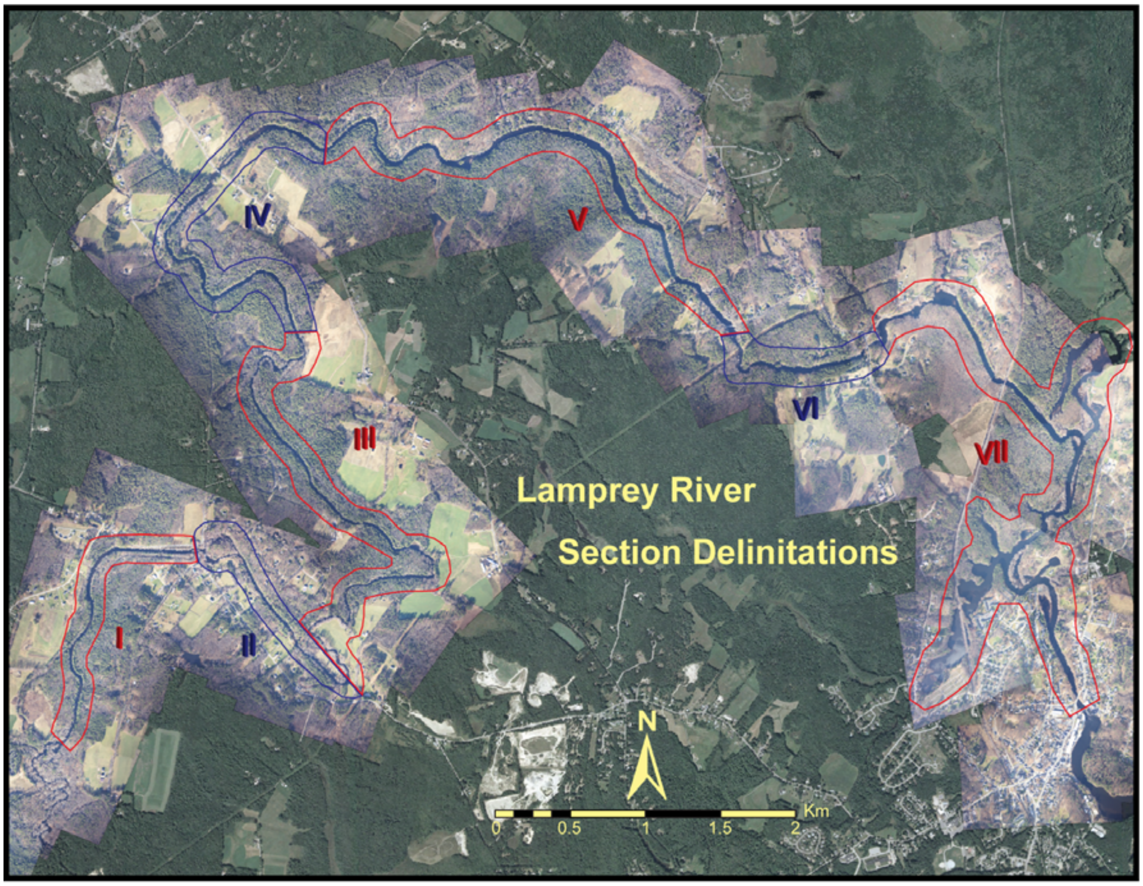


Figure 3-13. Locations of seven sections identified for the Lamprey River designated reach.

These particular periods of time, or bioperiods, have been identified for the diadromous fish species of the Lamprey River and then compared to the corresponding mean flow values for the Lamprey River to identify the times and flows that are critically important to the reproductive success of these species within the river. Six species of diadromous fishes have the potential to occur within the Lamprey River. Four of these species, alewife (*Alosa pseudoherangus*), Atlantic salmon (*Salmo salar*), American eel (*Anguilla rostrata*), and blueback herring (*Alosa aestivalis*), were sampled within the designated study area during Lamprey River baseline fish sampling in 2003 (NHDES 2005). Two of these species, alewife and American eel, were among the most prevalent species in these samples and have been included in the Lamprey BFC. These two species will be evaluated using mesoHABSIM as described above. The other two species, Atlantic salmon and blueback herring, along with American shad (*Alosa sapidissima*), and sea lamprey (*Petromyzon marinus*), which could potentially occur within the designated study reach, will be considered for inclusion in the Reference Fish Community and may be evaluated using mesoHABSIM as described above.

Banded Sunfish (Enneacanthus obesus)

Banded sunfish, a species with limited distribution within the state of New Hampshire, prefer vegetated backwaters, impoundments, and areas of slow-moving water within lowland streams (Scarola 1987, Page and Burr 1991). David Carroll reported catching banded sunfish in turtle traps fished in the Lamprey River (Carroll 1996). The majority of all banded sunfish records are from the rapidly growing southeast part of New Hampshire (NHFG 2005). This species' specific habitat preferences and limited distribution to an area threatened by rapidly increasing populations, places a high value on the need for identifying and protecting their instream flow and habitat needs within the designated reach of the Lamprey River. This species will be considered for inclusion in the Reference Fish Community model and may be evaluated using MesoHABSIM as described above.

Bridle Shiner (Notropis bifrenatus)

The designated reach provides habitat for the bridle shiner (Cairns 2005). This fish species prefers sluggish mud bottomed pools of creeks and small to medium rivers, and is often found in areas of vegetation (Page and Burr 1991). Bridle shiner have been sampled at multiple stations within the designated study reach of the Lamprey River in 2003 during the Lamprey River Baseline Fish Sampling efforts (NHDES 2005). This species is considered one of the most prevalent fish species within the Lamprey River, based on presence and abundance, and has been included in the Lamprey BFC (NHDES 2005). Bridle shiner are experiencing population declines throughout their entire range (Sabo 2000). Within New Hampshire their distribution is almost entirely limited to the southeast portion of the state, an area experiencing rapid growth (NHFG 2005). Given the range-wide decline of this species and their limited distribution within New Hampshire, the flow needs of this species should be should be addressed to provide for the conservation of this species within the Lamprey River. This species will be evaluated using MesoHABSIM as described above.

Brook Trout (Salvelinus fontinalis)

Brook trout are dependent upon flow conditions that are favorable to the specific water quality conditions required of this species: cold, clean, well-oxygenated water with flowing riffles and pool habitat. They are unable to survive in water temperatures that exceed 20° C for any extended period of time (Scarola 1987). Brook trout are believed to have been far more abundant in the waters of New Hampshire historically (Noon 2003), and are currently experiencing population declines locally (New Hampshire), regionally (New England), and throughout their entire range (TU 2004). The upper portions of the designated reach provide potential habitat for brook trout. This species will be considered for inclusion in the Reference Fish Community model and may be evaluated using MesoHABSIM as described above.

Redfin Pickerel (Esox Americanus)

Redfin pickerel prefer habitats very similar to the banded sunfish and bridle shiner and are primarily limited within the state of New Hampshire to the southeastern part of the state (NHFG 2005). They inhabit shallow backwater areas of lowland streams, and are associated with areas of dense vegetation, woody debris, and leaf litter. They are tolerant of acidic, brackish, and poorly oxygenated water conditions. Redfin pickerel are dependent upon annual flooding episodes for access to spawning locations in the shallow vegetated backwaters of lowland streams (Scarola 1987).

Redfin pickerel were sampled on the Lamprey River in multiple locations within the designated study reach, both above and below Wiswall Dam, during the Lamprey River Baseline Fish Sampling efforts (NHDES 2005). This species limited distribution, specific habitat requirements and dependence upon marginal wetland floodplains makes it a species of conservation concern within the state of New Hampshire. Its presence at multiple sites within the designated study reach of the Lamprey River may suggest favorable habitat and flow conditions and could lead to the identification of other suitable habitats for this rare species. Redfin pickerel will be evaluated using MesoHABSIM as described above.

Swamp Darter (Etheostoma fusiforme)

The swamp darter prefers heavily vegetated, shallow areas of lakes, ponds, and streams (Scarola 1987). This species is not currently protected within the state of New Hampshire, and little research has been conducted regarding the distribution status or health of populations within the state (NHFG 2005). Populations of this species, in New Hampshire, seem to be limited to watersheds within the southeast portion of the state. The rapid development an increasing human population in this region may pose a threat to the habitats of this species. This threat of habitat loss, when combined with the fact that New Hampshire is on the northern cusp of this species known range and this species short life span (1-2 years), make the swamp darter vulnerable to local or even regional extirpation (NHFG 2005).

Two records of swamp darter exist from the Lamprey River in samples collected by the New Hampshire Fish and Game Department between 1983 and 1985 on the mainstem of the Lamprey River (LBFC 2005). There were no individuals of this species collected during extensive sampling efforts on the Lamprey River conducted in 2003 (NHDES 2005). This rare species, facing the threat of extirpation, should be evaluated to identify potential habitat existing within the designated study reach. It will be considered for inclusion in the Reference Fish Community model and may be evaluated using MesoHABSIM as described above.

Invertebrates

Brook Floater (*Alasmidonta varicose*)

The designated reach provides habitat for the brook floater; a state listed endangered mussel species. These mussels prefer areas of cobble/sand substrate with moderate current (Cairns 2005). Brook floaters are particularly sensitive to artificial flow regimes and face local extirpations, as a result of low population densities, under unfavorable flow conditions. On the Lamprey River brook floaters are scattered in very low numbers and are extremely vulnerable to inadequate flow conditions (NHFG 2005). The threat of local extirpation of this species from the Lamprey River exists if adequate flow conditions are not maintained. This species will be evaluated using MesoHABSIM as described above.

Wildlife

The New Hampshire Natural Heritage Bureau provided information regarding rare, threatened and endangered species, species of concern, and Exemplary natural communities along the Lamprey River study corridor. Field investigations previously performed by botanists and wildlife specialists, in part for the Wild and Scenic study, were also consulted for additional information regarding RTE species and their habitats.

Blandings Turtle (Emydoidea blandingii)

Blandings turtles (special concern species) prefer permanent shallow dark waters of bogs, swamps, ponds and slow moving rivers and coves, and the adjacent vegetation. They require shallow water with soft mud bottoms, and frequently nest in plowed fields near wetlands (DeGraaf and Yamasaki 2001). Most Blandings turtles have been observed upstream of the project area along the Lamprey

River. Several properties within the study area are known to support Blandings Turtles, including some large wetland complexes, some of which also may support spotted turtles. Blanding's Turtles typically require deeper water than spotted turtles, and do not seem to make sustained use of the river channel, but do use it at times, if only during long-term dispersal (Carroll 1998). There are additional potential habitats in the study area without confirmed Blanding Turtle populations.

As with spotted turtle habitat, reductions in flow that drain wetlands or expose the bottom of waterbodies for prolonged periods in winter and spring could cause stress or mortality of Blandings turtles. Water bodies potentially supporting Blandings Turtle that are located within the floodplain of the Lamprey River will be assessed using the Floodplain Transect Method.

Wood Turtle (Clemmys insculpta)

The wood turtle, a species of concern in New Hampshire, has been observed and documented in several locations within the Lamprey River study area by David Carroll, an experienced ecologist. The wood turtle has been classified as flow dependent species due to its reliance on riverine habitats in spring and summer for feeding and cover, and also for overwintering. The Wood Turtle overwinters on the bottoms of streams and feeds both on land and in the water (Taylor 1993) eating aquatic and upland plants and animals. Instream and riparian cover are extremely important for wood turtles (Carroll 2000). Instream cover includes deadfalls and debris drifts and dams, and cobbles and boulders. Natural wetland shrub borders along the river with herb cover, vines and debris and detritus provide cover for hatchlings through adults. Wide undeveloped riparian areas are best. Such habitat has been observed along the Lamprey and several of the larger tributary streams (Carroll 2000). Most of the wood turtles observed during David Carroll's studies were located upstream of the study area. However, suitable habitat appears to exist within the project area, though angling and other human activity may limit suitability. Wood turtles nest in dry, sandy, upland openings, which must be safely accessible from the river, but nest sites are typically above the floodplain and not flow dependent.

While loss of riparian habitat due to development is probably the greatest threat to this species in the watershed, changes in flow that cause the loss of bordering wetland shrubs (higher than normal summer flows, or lower than normal early growing season flows for years) could adversely affect wood turtle preferred habitat, and reduce survival. Flow changes that increase bank heights permanently would also adversely affect turtle habitat. Low winter flows that occur after the start of hibernation could expose hibernating turtles to ice or scour could result in direct mortality. This species is reported to be intolerant of pollution (DeGraaf and Yamasaki 2000), and therefore also indirectly flow dependent.

The flow regime proposed under the WMP will be examined to insure that fall and winter water flows and fluctuations are protective of hibernating turtles. The likely overwintering habitat will be examined during the low flow and winter habitat transect surveys, and the minimum flows sufficient to keep those areas inundated will be determined. Evaluation of flow effects on bordering shrub swamp habitat will also be considered in evaluating wood turtle flow dependence.

Spotted Turtle (Clemmys guttata)

Spotted turtles prefer heavily vegetated wetlands surrounding small and shallow bodies of water, such as small streams, ponds, vernal pools, and swamps. In winter, spotted turtles hibernate in water under tree root wads in vernal pools, or in wetlands, or the muddy bottoms of shallow waterbodies. Spotted turtles may aestivate in adjacent upland forests during the dry summer months (DeGraaf and

Yamasaki 2001). Potential habitat for spotted turtles appears to be present in forested floodplains with pools and swamps and oxbow marshes, and historical observations exist (Carroll 2000).

Reductions in flow that drain wetlands or expose the bottom of waterbodies for prolonged periods in winter and spring could cause stress or mortality of spotted turtles. As with Blandings Turtles, application of the Floodplain Transect Method will address spotted turtle habitat in floodplain wetlands.

Osprey (Pandion haliaetus)

The Osprey is a State-threatened bird-of-prey observed foraging over the Lamprey River during the September reconnaissance. Ospreys are known to nest in Great Bay and may forage up to 7 miles away (Vana-Miller 1987). Ospreys observed along the Lamprey River in summer could be transient individuals. Ospreys consume primarily fish from clear, unobstructed water bodies. They dive up to 3 feet into the water, and so are most likely to feed in the pools and reservoirs, not shallow riffle areas. Only changes in flow that eliminate pools, reduce fish abundance, increase turbidity, or increase aquatic plant cover are likely to affect ospreys. Flows that are protective of a healthy fish community will be protective of this species, so the MesoHABSIM model will be interpreted for osprey.

Bald Eagle (Haliaeetus leucocephalus)

Bald eagles are a federally threatened, state endangered species re-colonizing their historic range. Eagles nested in New Hampshire in 1989 after a 40-year absence, and continue to nest in several New Hampshire locations each year. In New Hampshire, bald eagles occur in relatively undisturbed forests along major rivers and lakes or near the coast. Eagles perch on, hunt from, and nest on tall coniferous and deciduous trees or snags near water. They prey primarily on fish and waterfowl, but are also noted for their scavenging. In winter, they leave the breeding areas and congregate in areas with large expanses of unfrozen, open water. A forest stand that offers protection from inclement winter weather is needed for communal night roosting. Night roosts are most often found near foraging areas, but may be further away if the roost is more protected. Bald eagles are observed each winter in the Androscoggin, Connecticut and Merrimack River Valleys, on Great Bay, and in the Lakes Region. Non-breeding adults and immatures are observed sporadically throughout the state year-round, including Great Bay. The Lamprey River may provide eagle foraging habitat at various times of the year. Flow changes in the Lamprey River that affect fish populations may have a slight impact on this very mobile bird of prey. This will be interpreted from the MesoHABSIM model.

Sedge Wren (Cistothorus platensis)

The sedge wren, a state endangered species, uses densely vegetated sedge meadows, wet hayfields, upland margins of ponds and marshes, and coastal brackish marshes, preferring drier marshes or wet meadows where there is little standing water and the ground is damp. Sedge wrens have low fidelity to both breeding and wintering sites, and readily abandon areas that become too wet or too dry through water level fluctuation. Meadows greater than 2 acres are preferred. Nesting in the northeast is low to the ground (within a foot), and initiated in late June or July and may coincide with seasonal stability of water levels in preferred habitats. Agricultural land borders the Lamprey in several locations, but may only be hydrologically connected in a few of these, notably near Lee Hook Road and north of Moat Island. The location of potential sedge wren habitat will need further investigation. Evaluation of flow effects will occur through the Floodplain Transect Model.

Pied-billed Grebe (Podolymbus podiceps)

Preferred habitat for the State-endangered Pied-Billed Grebe is densely vegetated emergent and deep marsh interspersed with open water that is more than 12 acres in size ((Degraaf and Yamasaki 2000; Banner 1998). To the extent that such a marsh is dependent on river flow, this marsh bird species would be flow dependent. A preliminary inspection of aerial photos of the Lamprey River floodplain indicates that there are several marshes that could be habitat for the Pied-billed Grebe, and some of these have a direct connection to the Lamprey River. The evaluation of flow-dependency for the Pied-billed Grebe is similar to that for Floodplains and Emergent Wetlands so the procedure detailed in the Floodplain Transect Model will be used to evaluate this species. Specific needs of the Pied-billed Grebe are that standing water must always be present.

Vegetation

Much of the information regarding RTE vegetation was obtained from records provided by the New Hampshire Natural Heritage Bureau in 2005 and from a comprehensive report prepared by Sperduto and Crow (1994) of the Natural Heritage Bureau. Individual RTE plant species are included, as well as one Exemplary Natural Community. Other natural communities are discussed in Section 3.1.4 Fish and Wildlife Habitat.

Climbing Hempweed (Mikania scandens)

This State-threatened plant was found in 1994, in a wetland along a tributary to the Lamprey River. Although this climbing facultative-wetland plant is likely flow dependent, it is not clear how influential the Lamprey River flows are on this wetland system. This species may not be Lamprey flow dependent, and further investigation is needed.

Small-crested Sedge (Carex cristatella)

This state-listed Threatened species is typically found in meadows, rich woods and along pond margins. The plant has not been relocated where it was historically identified in 1942. There is some evidence that it may have been misidentified. This will be reviewed with the Natural Heritage Bureau.

Star Duckweed (Lemna tricsulca)

Historical records indicate this floating-leaved aquatic bed species was collected from a tributary stream to the Lamprey River, but it was not observed in this location or elsewhere in the river in 1994 (Sperduto and Crow 1994). This obligate, state endangered species is most likely to be found in quiet backwaters and slow moving ditches.

Sharp-flowered Mannagrass (Glyceria acutiflora)

This state-listed endangered grass species is found in shallow water in ponds and streams, and blooms in June and July. The Natural Heritage Bureau database indicates that is was last observed in the Lamprey in 1942 in fast-flowing shallow water. A related species was observed at this location in 1994, but not the target plant. This plant species may or may not be extirpated from this site.

Water Marigold (Megalodonta beckii)

This aquatic member of the composite family is found in ponds, streams and slow rivers, blooming in August to September. It is currently listed as an endangered species in New Hampshire. It has been recorded from one particular location in the Lamprey River where it was locally abundant in 1994, and was also observed in a tributary stream above a culvert that hydrologically separates the plant community from the Lamprey River during most flows. We did not observe this species in 2005, but we likely missed its period of flowering.

Small Beggars tick (Bidens discoidea)

A new station was located for this flowering facultative-wetland species in 1994 in the project area, but it does not appear on the current RTE list of plants for New Hampshire, and presumably was removed from the list as it has been observed at numerous new sites.

Knotty Pondweed (Potamogeton nodosus)

This state endangered aquatic plant is found in shallow to deep ponds and streams, and was recorded as recently as 2004 in this portion of the Lamprey River. In 1994, the historic record was reconfirmed and found to be locally abundant in rapids throughout the study area, typically associated with riverweed (*Podostemum ceratophyllum)* and white water crowfoot *(Ranunculus trichophyllus*).

Slender Blueflag (Iris prismatica)

This state-listed threatened species is found in brackish to fresh wet meadows, bogs, pond margins and wooded swamps. It blooms in June and July. This species was not mentioned in the 1994 survey by the Natural Heritage Bureau. A search for this flow-dependent species will be undertaken in the summer of 2006.

Natural/Ecological Communities

Swamp White Oak (Quercus bicolor) Floodplain Forest

Floodplain forests dominated or co-dominated by swamp white oak are state and regionally rare, classified as S1 (Sperduto and Nichols 2004). These floodplain communities average approximately 1 to 6 feet above the main river channel. Based on the characteristic flora observed during the preliminary IPUOCR survey in the known swamp white oak community along a tributary to the Lamprey, both high and low variants of this community are present. This swamp is temporarily to seasonally flooded, and the degree to which it is dependent on Lamprey River flows is undetermined. Several slow streams flow through the swamp into the Lamprey River. This site, described as “outstanding” by the Natural Heritage Bureau, is the only swamp of its kind known from the watershed. Many of the other plants are typical of the lower floodplain forests found along the Lamprey River. Floodplain forests are dependent on spring floods to provide nutrients seasonally and discourage colonization of upland species. The flood intensity and duration of flooding are typically lower than for silver maple floodplain forests on larger rivers, and the flooding may occur earlier in the year.

Reduction in spring floods over long periods or increases in flooding intensity or duration may alter the plant community. The low elevation variant type may be more susceptible to affects from changes in flow. The relationship between flows in the tributary and flows in the Lamprey River will be explored during the flow analysis, and the effects of flow on the swamp white oak floodplain forest will be assessed using the Floodplain Transect Model, if appropriate.

3.1.6 Public Water Supply

In the New Hampshire Laws of 1965, Chapter 332, the New Hampshire Legislature preserved the Lamprey River water for seven towns through which it runs. This law will form a basis for these seven towns to expect the Lamprey River to supply water in an amount adequate to support domestic potable water needs. At this writing, the Durham/UNH water system makes a direct withdrawal from the Lamprey River from the impoundment behind Wiswall Dam. The Town of Newmarket has the ability to withdraw from Follett's Brook, the Piscassic River, and the Lamprey River, and they have historically done so. The Town of Newmarket has been searching for new water sources for the past decade, and may investigate using Lamprey River water for artificial recharge of their Newmarket Plains aquifer. Newmarket has a water treatment plant located on the Piscassic River that can treat surface water, however the plant is rarely used due to a variety of reasons. Due to strong regional development pressure, the Lamprey River will be studied as a water supply by towns extending as far west as Northwood and Deerfield.

Other towns (Epping, Raymond, and Newmarket) have groundwater supply wells that supply their respective water supply system. The hydrogeologic investigation to be conducted as a part of Task 2 will result in a clearer delineation of the relationship between these wells and river flow: that is the ability of wells to induce recharge from the river. If these wells are substantially connected to the river and creating induced recharge, the influence of the operation of these wells on river flows and achieving instream flows will be examined further as part of the water management plan. Although low river flow may be associated with low groundwater levels and therefore possibly lower well yields, maintaining high river flows in order to support enhanced well yields is an extremely inefficient mechanism and management strategy, and therefore is not considered. The scope of the present study was clearly delineated to focus on large groundwater withdrawals within 500 ft of the Designated River and its tributaries. It is recognized that groundwater withdrawals and instream flows are watershed issues, and that a complete study would assess the effects and management strategies of all water uses within the Lamprey River watershed. The complexity of this issue and the uncertainty involved in predicting low flow periods lead to the limitation that only wells within 500 feet of the river be included in this instream flow study. During average to wet periods, all water users may be satisfied. During low flow times, there may be habitat stress. Habitat stress may be relieved by reducing groundwater withdrawals. However, one must recognize that the groundwater-river flow connection has a delayed response to the reduction in groundwater withdrawals: the farther wells are from the river, the longer the delay, and possibly the inability of the reduced groundwater withdrawals to relieve habitat stress. Stakeholder-NHDES discussions, prior to the performance of this instream flow study, recognized the complexity and reality of the groundwater-river flow connection, and these discussions resulted in the 500 foot limit for large groundwater withdrawals. There are very few registered wells that do not fall within 500 feet of the Designated River or one of its tributaries.

3.1.7 Environmental/Fish Habitat

River Morphology and Aquatic Habitat

Aerial photographs and visual observation of the river indicate the form varies throughout its length. Characteristics such as oxbows and meanders can be determined from maps and photographs, while substrate, width, depth and other characteristics need to be viewed at the small scale. Flow has the ability to alter the morphology of the river. The Lamprey River channel cuts through numerous ledges that define its morphological character. The morphological character of the Lamprey ranges from a high gradient, straightened third order stream to a low gradient meandering fourth order river and 46 % of the designated area is impounded. Figure 3-13 documents the location of the seven sections identified for the Lamprey River designated reach. The high gradient portion of the designated reach is located directly downstream of the confluence of the North River where it is constricted by bedrock outcrops. This section is one of the few free, but slow flowing portions of the Lamprey River accompanied by forest and wetlands. The section ends with a former impoundment upstream of Wadleigh Falls. Downstream of this partially breached dam the river first splits into two channels surrounding an island. Below the island the straight alignment causes us to speculate on the possibility of some historical channelization or entrenchement. The river is about 20 m wide, with a relatively high gradient and almost closed canopy cover. In this upstream portion (our sections 1-24), the average width is 5 to 15 meters and the river is characterized by a relatively shallow and fast flowing current. Below the confluence with Stony Brook the river maintains a high gradient until our Section 3.3. At the end of this section, the Lamprey River makes an almost 180 turn adjacent to Tuttle Swamp at Newmarket Plains. Downstream the river begins to wind between the hills and in the forest and is still relatively narrow (about 20 m). Just upstream of Lee Hook Road the river widens to 30 m and slows down due to the backwater effect created by bedrock outcropping and rapids just upstream and downstream of the Lee Hook Road bridge. The river continues to flow until the beginning of the Wiswall impoundment which creates a fifth section. Below Wiswall Dam there is a series of bedrock outcrops that create the multiple waterfalls, rapids and pools of section six. Shortly downstream of Packer Falls the river is impounded again all the way to the end of the DR.

3.2 NON-FLOW DEPENDENT ENTITIES

Non-flow dependent entities are defined as those entities that do not directly depend on a prescribed minimum flow for their existence or survival. In some instances, non-flow dependent entities are dependent on flow dependent entities (for example wildlife that feeds on fish); in this case, the prescribed minimum flow would be based on the fish. If flows are sufficient to support fish then the wildlife would be sufficiently protected. In other instances the IPUOCR is related to a water use but not completely dependent on it. For example, a golf course uses water for irrigation but will not close if sufficient water is not available. These IPUOCR are defined as non-flow dependent but will be addressed in the water management plan as water users.

3.2.1 Storage

There is 1 dam listed in the NHDES dams database on the designated reach (NHDES 2004):

Table 3-4. Listed Dams in the Designated River.

Impoundment Name	Location
Wiswall Dam	Durham

This dam on the designated reach is operated essentially as a run-of-the-river operation. There are no large impoundments within the designated reach. Therefore, no opportunities for large amounts of storage within the designated system exist. There are a number of dams in the watershed, but few with large amounts of storage that could be accessed during low flow periods. The impoundments are essentially full most of the time precluding the need for water to refill after drawdown. Some of the dams are considered affected dam owners (ADO's) for purposes of this study, while others are not. Dams with impoundment areas of less than 10 acres are considered non-ADO dams. Options for the management of river flows in the designated reach with water from all available storage will be included in the water management plan.

Surface water storage volume in reservoirs typically is reserved for one of three purposes: sedimentation, conservation, or flood control. The sediment storage is reserved for the sediment build-up over the life of the reservoir. Conservation storage is water that is released to meet needs (for example, irrigation or hydropower) or maintained to meet needs (for example, recreation). Flood storage is empty space available to be filled during flooding events. The objective for conservation storage is to be full all the time. The objective for flood control storage is to be empty all of the time. Per se, these types of storage themselves are therefore not flow dependant. The uses of the storage are flow dependant, and these uses are treated as their own separate IPUOCR categories. Therefore as an IPUOCR, storage is determined not to be flow dependent.

3.2.2 Recreation

Recreation resources in the vicinity of the designated reach include: Locations used for hiking, nature study, fishing access, picnicking, winter sports and such include:

- Doe Farm Forest, owned by the Town of Durham;
- Wiswall Road Area, owned by the Town of Durham;
- Packers Falls Recreational Area, owned by the Town of Durham;
- Thompson Farm, Durham;
- Ferndale Acres Campground, Lee;
- Lamprey River Campground, Lee;
- Wellington Campground, Lee;
- Piscassic Street Park, Newmarket.

The sites and activities listed above are not classified as flow dependent. The prescribed flow which will include sufficient flow in the river to maintain the aquatic environment will be sufficient to preserve the scenic value of the river.

3.2.3 Conservation/Open Space

Open Space parcels include the following:

- Durham: The eighty acre Doe Farm Forest contains 750' of river frontage along with extensive trails. Within the town of Durham, there is an additional 7 miles of undeveloped river frontage that is largely undeveloped.

- Lee: Within the town of Lee, eight properties account for 7.8 miles of river frontage that is bordered by wooded habitat and fields.

The prescribed flow which will include sufficient flow in the river to maintain the aquatic environment will be sufficient to preserve the scenic value of the river.

3.2.4 Maintenance and Enhancement of Aquatic and Fish Life

Management of Exotic/Invasive Species

There are exotic and invasive species of vegetation and invertebrates present in New Hampshire, which have the potential for causing harm to the watershed. These species can be found listed on the New Hampshire Department of Environmental Services website. For the purposes of this project, these species are not IPUOCRs, although some are flow-dependent. Rather, these species are threats to an IPUOCR – namely the communities of native plants and their habitat value. Maintenance and protection of these natural communities (and control of invasives) is assumed to be facilitated under the Natural Flow Paradigm, which should favor the adapted native plants. But invasive species may be favored when deviations from the natural flow paradigm occur. The potential for increases in the species mentioned below will be evaluated during the Floodplain Transect/seasonal water level modeling.

Several wetland and upland invasive species were observed during the field reconnaissance, including Purple Loosestrife (*Lythrum salicaria*), a species that relies on water transport of seed to spread and germinates in seasonally exposed mudflats. This is a perennial species that increases in periods of low flow, and could become more abundant if low water conditions are prolonged. Japanese knotweed (*Polygonum cuspidatum*) is a persistent perennial that spreads rapidly by rhizomes, fragments of which are often transported by water. Though such transport is possible at any flow, it is most likely to occur at high flows. The wind dispersed seed rarely germinates. This plant was observed on the riverbank in some locations, and is likely to spread regardless of flow. These and several other invasive species, including common barberry (*Berberis vulgaris*) and Europeran buckthorn (*Frangula alnus),* were observed during the detailed 1993 and 1994 vegetation assessments (Chase 1993, Sperduto and Crow 1994). No invasive submerged aquatic macrophytes were recorded. A flow regime that encourages a healthy native community of flora and fauna in the designated reach will discourage the spread of exotic/invasive species.

3.2.5 RTE: Fish, Wildlife, Vegetation or Natural/Ecological Communities

Wildlife

Peregrine Falcon (Falco peregrinus)

The state endangered peregrine falcon has been observed in the four lower Lamprey towns (NHDES 2004), and may be observed in open country, from coastal lowlands to mountainous high country. After the population was decimated by the effects of DDT, breeding pairs in New Hampshire were re-established through a captive-breeding program and are again present at some of their traditional breeding cliffs. The nest is often a hollow, unlined scrape on a cliff, ledge or rocky outcrop. Abandoned raven or hawk nests in high locations are occasionally used, as well as roofs and ledges of city buildings and large bridges. The same nest site may be used for many years. There are no known nest sites along the Lamprey River. Peregrines feed on birds, bats, and dragonflies, capturing their prey in mid-air by diving and striking the prey with closed feet and plucking the prey from the air with sharp talons. Peregrines are not flow dependent.

Eastern hog-nosed snake (Heterodon platyrhinos)

The state threatened hognose snake can be found in sandy woodlands such as pine barrens and oak woods; fields, farmland and coastal areas. Sandy soils are an essential habitat characteristic. Toads are their preferred prey, although frogs, salamanders, small mammals, birds and invertebrates are also taken. One unconfirmed report of a hognose snake in the Lamprey River area was reported (NHDES 2004). The hognose snake is not flow dependent, although they may use sandy floodplain areas along Rivers.

Non-RTE Wildlife

Several other birds of conservation concern in New Hampshire have been reportedly observed within the watershed or even floodplain of the Lamprey River. These include the red-shouldered hawk, whip-poor-will, bobolink, eastern meadowlark, least flycatcher, wood thrush and American redstart, species at risk due to habitat loss or other concerns. While not flow dependent, these species may find appropriate habitat along the Lamprey River. A great blue heron rookery is reportedly located in a large beaver marsh that adjoins the Lamprey River. While herons often build nests in flooded forested wetlands that may be hydrologically connected to a river, the presence of a particular water level is not generally considered critical, and rookeries are sometimes located in upland forests.

Informal observations of non-flow dependent reptiles and amphibians include several species of snake (smooth green snake, common garter snake, eastern ringneck, black racer, milk snake, and redbelly snake) and a salamander (redback salamander).

Vegetation

Philadelphia panic-grass (Panicum philadelphicum)

Philadelphia panic-grass flowers from June-October in a variety of habitats from dry open woods and fields to moist shores of lakes and streams. It is listed in New Hampshire as an endangered species that is widespread in its range, but historical in New Hampshire. It potentially occupies a wide range from Georgia to east Texas, north to Nova Scotia and southwestern Quebec, west to Ontario, Minnesota, Iowa, Kansas, and Oklahoma. Its broad habitat associations identify it as likely non flow dependent.

Northern blazing star (Liatris scariosa)

Northern blazing star, a state endangered species, grows in dry, open grassy habitat. In New Hampshire it is found primarily on sandplains in clearings or in dry open pitch pine and oak barrens. It also occurs on dry river bluffs, on gravelly slopes, and nea rrailroad tracks in association with these areas. These are generally early-successional habitats, characterized by nutrient-poor, sandy soils that only support relatively sparse vegetation. Fire has historically played a role in maintaining these open habitats and seems to have a positive effect on this species as well. The plants are not tolerant of shade and decline in undisturbed areas where later-successional species such as shrubs and trees move in. This species is not associated with lower river channels or floodplains, and is not flow dependent.

Blunt-lobe woodsia (Woodsia obtusa)

The blunt-lobed woodsia is a state endangered species that is widespread and secure further south in the United States. This fern grows on rocks or cliffs in deciduous forests and is sometimes associated with other native ferns. At its northern limit in Canada, it appears to favor south-facing slopes for milder weather. This species has been reported from a rock outcrop near the Lamprey River in a birch, ash, oak and hickory forest above the influence of river flows, and from approximately 4 other New Hampshire sites. This species is not flow dependent.

Missouri rock cress (Arabis missouriensis)

Missouri rock-cress is one of several similar rock-loving plants belonging to the Mustard family. It favors circumneutral bluffs, ledges or rocky woods in hardwood or mixed forests. There are some questions regarding the taxonomy and/or global rank of this state threatened species. This plant was recorded from the a site near the Lamprey River, but searches during the vegetation inventory (Sperduto and Crow 1994) did not reveal any populations. Based on the preferred habitats, this plant is not flow dependent.

Downy false foxglove (Aureolaria virginica)

The state endangered downy false foxglove is reported to be parasitic on the roots of species of white oaks. This plant prefers dry-mesic, open oak, woodland slopes with a southern aspect, and tolerates/benefits from some periodic disturbances that maintain a relatively open canopy. This plant was reported along the Lamprey River, but was not found during the searches of 1994 (Sperduto and Crow 1994). The dry-mesic oak woodland slopes are likely to be above the zone influenced by river flow, and this species is not considered flow dependent.

3.2.6 Water Quality Protection/Public Health

The river generally supports its water quality classification, class B, at all locations. According to the Lamprey River Management Plan (LRAC 1995), certain sites exceeded acceptable limits for bacteria and are below limits for dissolved oxygen. The report also suggests that chlorophyll a concentrations are occasionally high and zinc criteria are sometimes exceeded during low flow periods. The recent 303d list of impaired waters (NHDES 2004) lists portions of the Lamprey as impaired with respect to pH, mercury, dissolved oxygen and bacteria. The biotic integrity of the waterbody does show signs of impairment and degradation. However, cold-water and pollutant intolerant non-game species are present in the Lamprey, indicating that chemical and physical water quality conditions are favorable to supporting a diverse cold and warm water fishery. Recent NHDES and Lamprey volunteer monitoring program water quality data will be reviewed to insure that this IPUOCR is still correctly classified as non-flow dependent.

3.2.7 Pollution Abatement

The Epping WWTF (wastewater) is the only discharger to the Lamprey. The discharge location is above the designated reach.

The project team will review wasteload allocations and permits as well as superfund reports and relate prescribed protective flows to the discharge. The TMDL report for the Lamprey completed in 1995 is expected to provide the most recent analysis. Regional wastewater plans with the potential to influence flows in the Lamprey will also be reviewed

3.2.8 Aesthetic Beauty/Scenic

A large proportion of undeveloped land makes the Lamprey a valuable resource in terms of scenic beauty. These areas include three scenic waterfall areas: Wadleigh Falls in Lee and Wiswall and Packer's Falls in Durham. Good views of the river are available at the Wadleigh Falls Road, Lee

Hook Road, Wiswall Road and Packer's Falls Road bridge crossings. The prescribed flow which will include sufficient flow in the river to maintain the aquatic environment will be sufficient to preserve the scenic value of the river.

3.2.9 Cultural/Community Significance

The river is discussed in each of the municipal master plans and is recognized as a significant community resource. The Lamprey River Advisory Committee includes representatives from the towns of Durham, Epping, Lee and Newmarket. They are in charge of developing and implementing a river management plan under the New Hampshire State River Management and Protection Program. The Lamprey River Watershed Association plays a key role in the protection and preservation of the river. They are involved in land protection, water quality monitoring and publication of a layman's water quality monitoring guide, public education, recreational activities, assistance with waterfront development proposals and the Lamprey's designation as a Wild and Scenic River.

3.2.10 Historical or Archaeological

According to the New Hampshire Division of Historical Resources, New Hampshire Archaeological Inventory, there is one site of historical significance within 100 meters of the Lamprey River along the designated reach. This site is located in Durham (Wiswall Falls Mill Site – address restricted. Listed 03-18-1988). Historical and archeological information is sensitive in nature therefore specific site locations are not identified in public documents. Wiswall Falls has had some archaeological exploration, mostly 19th century artifacts, colonial material, and evidence of ancient Indian residence.

Wadleigh Falls in Lee, is recognized as one of the earliest and the states most important archaelogical sites. It is "rich in prehistoric cultural remains found in an undisturbed context".

3.2.11 Hydrological/Geological

Aquifers

From Epping and westward, stratified drift aquifers underlie and parallel the Lamprey River. In the eastern watershed towns of Epping, Lee, Durham, Newmarket, and Newfields, the stratified drift aquifers form a patchwork across the region. Saturated thicknesses can range from a few feet to over one hundred feet. In some locations, the stratified drift is overlain by a marine clay, thereby confining the stratified drift aquifers in these locations. In general, the Lamprey River and its tributaries serve as discharge locations for both overburden and bedrock groundwaters. In some locations, the river can recharge aquifers, but this does not appear to be areally extensive except during river flood stages. Stratified drift can be highly transmissive and in some places yield 100's of gallons per minute to wells. Frequently, these same locations were used for waste disposal, rendering large portions of such formations contaminated. Stratified drift transmissivities range from 10 to 10,000 square feet per day.

The bedrock that underlies the watershed ranges from igneous to metamorphic. In general, the bedrock has low transmissivity (range of 1 to 100 square feet per day). However in locations having large fractures or fracture intersections, the bedrock can yield substantial amounts of water (over 400 gallons per minute). Bedrock is predominantly confined, except in outcrop areas, and therefore the bedrock commonly discharges to overlying features (wetlands, overburden, water bodies).

During extreme low-flow events, aquifer recharge to the river (baseflow) will be reduced. Due to the relatively slow reaction of groundwater hydrology to surface water hydrology, for this study, this IPUOCR is not considered to be flow dependent.

3.2.12 Agricultural

Agricultural properties along the river include

- Brady on Route 152 below Wadleigh Falls, Lee
- Athemore Dairy Farm, Lee Hook Road, Lee
- University of New Hampshire, Lee Hook Road, Lee
- Unnamed, Lee Hook Road, Lee

Agricultural uses of water will be addressed in the water management plan.

4.0 REFERENCES

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APPENDIX A

Fish and Invertebrate Species, Characteristics, and Habitat

Biological Summary of Order (Odonata)

A. Life History

1. Eggs - usually several hundred to several thousand; either in water or in plants; usually hatch in several days to 1 month
2. Nymphal Stage (immature stage) - nymphs; usually approximately 1 year (ranges from 3 weeks to 5 years)
3. Adults
   A. Most species live 40 to 50 days
   B. Crawl out of water to molt
4. Number of generations per year - most univoltine (some semivoltine or merovoltine)
5. Time of emergence - most spring and summer (some early fall)
6. Delays in development – during periods of adverse abiotic conditions diapause in the egg stage may commence for periods up to 7 months.

B. Habitat and Habits

1. Adults – many disperse widely but return to spend most of adult life near preferred aquatic habitat (not necessarily their natal habitat); some fly almost all of the time, others perch for short periods between flights
2. Nymphs – dragonflies common in slow–moving flowing waters and standing waters; not many damselflies found in flowing waters; nymphs move rather slowly, if at all; lie in soft sediment or climb about in vegetation or plant debris

C. Food

1. Adults
   A. Capture insects with spines on front legs
   B. Large eyes, 360 degrees to capture prey
2. Nymphs - capture invertebrates (anything they can subdue) with hinged labium

D. Respiration of Immature Stages

Closed tracheal system with gills at end of abdomen; external in damselflies, internal in dragonflies

E. Behavior

Adults - male dragonflies defend territories; unique copulatory loop; some males remain with females during oviposition

F. Significance

Important source of food for many fish species. Odonates are also important predators of mosquitoes and other biting flies associated with aquatic habitats.

Key to Information

(f): Female.

(m): Male.

SL (Standard Length): The measured straight-line distance from the most forward point of the head to the hidden base of the tail, as indicated by the crease formed when the tail is bent to one side.

TL (Total Length): The measured straight-line distance from the most forward point of the head to the end of the tail fin, with the lobes of the tail fin compressed.

Reproductive Guild: A group with similar strategies to raise their young (i.e., parental care).

> *Nonguarders: Open substratum spawners: Pelagophils - Large quantities of non-adhesive, near-neutral or buoyant eggs are scattered in open water. No parental care of eggs.*
>
> *Nonguarders: open substratum spawners: Litho-pelagophils - Eggs are deposited on rocks and gravel, but eggs, embryos or larvae become sufficiently buoyant to be carried away from the spawning substrate by water currents. No parental care of eggs.*
>
> *Nonguarders: Open substratum spawners: Phyto-lithophils - Deposit eggs in relatively clearwater habitats on submerged plants, if available, or on other submerged items such as rocks, logs or gravel, where their embryos and larvae develop. No parental care of eggs.*
>
> *Nonguarders: Open substratum spawners: Phytophils - Scatter or deposit eggs with an adhesive membrane that sticks to submerged, alive or dead, aquatic plants or to recently flooded terrestrial vegetation. Sometimes woody debris. No parental care of eggs.*
>
> *Nonguarders: Open substratum spawners: Psammophils - Usually small eggs with an adhesive membrane that are scattered directly on sand and/or the fine roots of plants that hang over the sandy bottom. No parental care of eggs.*
>
> *Nonguarders: Brood Hiders: Lithophils - Eggs are hidden in specially constructed places. In most cases the hiding places (called redds in salmonids) are excavated in gravel by the female. No parental care of eggs*
>
> *Nonguarders: Brood Hiders: Speleophils - Usually few large eggs with an adhesive membrane that are hidden in crevices. No parental care of eggs.*
>
> *Guarders: Substratum choosers: Lithophils - Choose rocks for attachment of their eggs. Eggs are guarded, and possibly and ventilated.*
>
> *Guarders: Substratum choosers: Phytophils - Choose plants for attachment of their eggs. Eggs are guarded, and possibly and ventilated.*
>
> *Guarders: Nest spawners: Polyphils - No particular nest building material or substrate is chosen, however, a nest is constructed and the nest and eggs are guarded.*
>
> *Guarders: Nest spawners: Lithophils - Eggs are deposited on cleaned areas of rocks or in pits dug in gravel. Nest is guarded.*

Guarders: Nest spawners: Ariadnophils - *The nest building male has the ability to spin a viscid thread from a kidney secretion, which binds the nest of different material together. The eggs are guarded and ventilated by the male, who also guards the young once they hatch.*

Guarders: Nest spawners: Phytophils - *Eggs are deposited in nests constructed above or on a soft muddy bottom, often amid algae or other exposed roots of vascular plants. Nest is guarded.*

Guarders: Nest spawners: Speleophils - These fishes guard a clutch of eggs in natural holes or cavities, in specially constructed burrows, or where deposited on a cleaned area of the undersurface of flat stones.

Fresh Water Eel Family *(Anguillidae)*

American Eel *(Anguilla rostrata)*
The American eel has a catadromous life strategy; that is the eggs hatch in the sea, the young migrate to freshwater to grow, and the adults return to the sea to spawn.

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	top carnivore
Habitat Preference	near cover over muddy, silty bottoms of lakes, rivers and creeks; preferred water temperature ~19.0 ºC
Reproductive Guild	Nonguarders: Open substratum spawners: Litho-pelagophils
Spawning Habitat(s)	marine
Spawning Season	winter
Spawning Months	January-March
Spawning Temp	~17º C
Nursery habitat(s)	marine; estuarine; riverine
Diet	na
Age at maturity (yrs)	3-10 (m), 4-18(f)
Adult Length (cm)	25-40 TL (m), 70-100 TL (f)

Sucker Family *(Catostomidae)*

White Sucker *(Catostomus commersoni)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	generalist feeder
Habitat Preference	rocky pools and riffles of creeks and rivers; lake embayments; preferred water temperature ~22ºC
Reproductive Guild	Nonguarders: Open substratum spawners: Litho-pelagophils
Spawning Habitat(s)	lacustrine; riverine, migrate upstream to tributaries, or shoal areas if tributaries are not available
Spawning Season	spring
Spawning Months	April-May
Spawning Temp	~7-10ºC
Nursery habitat(s)	lacustrine; riverine
Diet	benthic invertebrates, fish eggs, larval midges, detritus
Age at maturity (yrs)	2-3 (m), 3-4 (f)
Adult Length (cm)	30.5-50.8 TL

Creek Chubsucker *(Erimyzon oblongus)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	generalist feeder
Habitat Preference	creeks, streams, and lakes with moderate aquatic vegetation
Reproductive Guild	na
Spawning Habitat(s)	lacustrine; riverine, gravel runs; young move to downstream habitats after hatching
Spawning Season	spring
Spawning Months	na
Spawning Temp	na
Nursery habitat(s)	lacustrine; riverine
Diet	plant material, a wide variety of aquatic and terrestrial invertebrates
Age at maturity (yrs)	na
Adult Length (cm)	Usually less than 22.8 TL

Sunfish and Black Bass Family *(Centrarchidae)*

Rock Bass *(Amblolpites rupestris)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	warmwater
Trophic Class	top carnivore
Habitat Preference	clear, rocky-bottomed runs and flowing pools of small to large rivers with; shallow, rocky and areas of lakes
Reproductive Guild	Guarders: Nest spawners: Polyphils
Spawning Habitat(s)	lacustrine; riverine
Spawning Season	spring
Spawning Months	June
Spawning Temp	~15.5-21.1ºC
Nursery habitat(s)	lacustrine; riverine
Diet	generally, smaller individuals consume aquatic invertebrates, primarily zooplankton, and occasionally small fish, larger individuals mainly feed on crayfishes and fishes
Age at maturity (yrs)	1-3
Adult Length (cm)	15.2-30.5 TL

Banded Sunfish *(Enneacanthus obesus)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	warmwater
Trophic Class	generalist feeder
Habitat Preference	Lowland, weedy lakes, quiet weedy backwaters of lowland brownwater streams.
Reproductive Guild	Guarders: Nest spawners: Polyphils
Spawning Habitat(s)	lacustrine; riverine
Spawning Season	spring-summer
Spawning Months	April-July
Spawning Temp	~11-28ºC
Nursery habitat(s)	lacustrine; riverine
Diet	wide range of small aquatic invertebrates, especially those bottom dwelling or in vegetation
Age at maturity (yrs)	1-2
Adult Length (cm)	7.6-8.9 TL

Redbreast Sunfish *(Lepomis auritus)*

General Habitat(s)	lacustrine; riverine
Pelagic	na
Thermal Regime	warmwater
Trophic Class	generalist feeder
Habitat Preference	clean water with rocky substrates; ponds, lakes, slow moving sections of streams and rivers; tend to avoid heavily vegetated areas
Reproductive Guild	Guarders: Nest spawners: Polyphils
Spawning Habitat(s)	sheltered areas: rocks and woody debris; build nests in sand or gravel substrate
Spawning Season	spring-summer
Spawning Months	May-august
Spawning Temp	na
Nursery habitat(s)	lacustrine; riverine
Diet	wide variety of larval and adult aquatic insects, including mayflies, caddisflies, midges, flies, mosquitoes, beetles, and dragonflies; scuds, aquatic snowbugs, mollusks, and small fishes occasionally eaten
Age at maturity (yrs)	na
Adult Length (cm)	10.1-20.3 TL

Pumpkinseed *(Lepomis gibbosus)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	warmwater
Trophic Class	generalist feeder
Habitat Preference	warm, shallow, vegetated lakes and ponds; quiet vegetated pools of creeks and small rivers; preferred water temperature ~26.0°C
Reproductive Guild	Guarders: Nest spawners: Polyphils
Spawning Habitat(s)	lacustrine; riverine; sand or gravel substrate
Spawning Season	spring-summer
Spawning Months	May-August
Spawning Temp	~20-28ºC
Nursery habitat(s)	lacustrine; riverine
Diet	wide range of aquatic invertebrates, especially those bottom dwelling or in vegetation
Age at maturity (yrs)	1-3
Adult Length (cm)	12.7-19.0 TL

Bluegill *(Lepomis macrochirus)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	warmwater
Trophic Class	generalist feeder
Habitat Preference	warm, shallow, vegetated lakes and ponds; quiet vegetated pools of creeks and small rivers; preferred water temperature ~26.0°C
Reproductive Guild	Guarders: Nest spawners: Polyphils
Spawning Habitat(s)	lacustrine; riverine; sand or gravel substrate
Spawning Season	spring-early fall
Spawning Months	May-September
Spawning Temp	~20-28ºC
Nursery habitat(s)	lacustrine; riverine
Diet	wide range of aquatic invertebrates, especially those bottom dwelling or in vegetation, small fishes, fish eggs, and aquatic vegetation
Age at maturity (yrs)	1-3
Adult Length (cm)	12.7-23.0 TL

Smallmouth Bass *(Micropterus dolomieu)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	warmwater
Trophic Class	top carnivore
Habitat Preference	clear, gravel-bottomed runs and flowing pools of small to large rivers; shallow, rocky and sandy areas of lakes; preferred water temperature ~30°C
Reproductive Guild	Guarders: Nest spawners: Polyphils
Spawning Habitat(s)	lacustrine; riverine
Spawning Season	spring
Spawning Months	May-June
Spawning Temp	~13-20ºC
Nursery habitat(s)	lacustrine; riverine
Diet	generally, smaller individuals consume aquatic invertebrates, primarily zooplankton, and occasionally small fish, larger smallmouths mainly feed on crayfishes and fishes
Age at maturity (yrs)	3-5 (m), 4-6 (f)
Adult Length (cm)	25.4-40.6 TL

Largemouth Bass (Micropterus salmoides)

General Habitat(s)	Lacustrine; riverine
Pelagic	no
Thermal Regime	warmwater
Trophic Class	Top carnivore
Habitat Preference	clear, warm, shallow lakes, bays, ponds, marshes and backwaters and pools of creeks and small to large rivers; often associated with soft mud or sand substrate and dense aquatic vegetation; usually at depths <6 m; preferred water temperature ~30°C
Reproductive Guild	Guarders: Nest spawners: Polyphils
Spawning Habitat(s)	Lacustrine; riverine
Spawning Season	Spring
Spawning Months	May-June
Spawning Temp	~17-22ºC
Nursery habitat(s)	Lacustrine; riverine
Diet	Young feed primarily on aquatic invertebrates and small fishes, as they mature fish become a greater part of their diet, sometimes larger individuals consume small mammals and birds
Age at maturity (yrs)	3-4(m), 4-5 (f)
Adult Length (cm)	30.5-53.3 TL

Black Crappie *(Pomoxis nigromaculatus)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	warmwater
Trophic Class	Top carnivore
Habitat Preference	Quiet, weedy waters of lakes, ponds, and streams
Reproductive Guild	Guarders: Nest spawners: Polyphils
Spawning Habitat(s)	lacustrine; riverine; sand or mud bottom, 3-8 feet deep, partly vegetated
Spawning Season	spring
Spawning Months	May-June
Spawning Temp	~14.4-17.7ºC
Nursery habitat(s)	lacustrine; riverine
Diet	wide range of aquatic invertebrates, and small fishes
Age at maturity (yrs)	2-4
Adult Length (cm)	12.7-30.5 TL

<u>Herring Family *(Clupeidae)*</u>

Blueback Herring *(Alosa aestivalis)*
The blueback herring is an anadromous fish, living in the ocean and migrating to freshwater to spawn. Juveniles remain in freshwater to mid-fall before migrating to sea.

General Habitat(s)	Marine; riverine
Pelagic	yes
Thermal Regime	na
Trophic Class	Generalist feeder
Habitat Preference	Gregarious; little is known about their specific habits and movements in Atlantic coastal waters
Reproductive Guild	Nonguarders: Open substratum spawners: Phytophils
Spawning Habitat(s)	riverine
Spawning Season	Spring-early summer
Spawning Months	Late May-June
Spawning Temp	~17.7-23.8ºC
Nursery habitat(s)	riverine
Diet	Freshwater: small invertebrates; Saltwater: planktonic crustaceans, shrimps, and fish larvae
Age at maturity (yrs)	2-3
Adult Length (cm)	~20.0-30.0 TL

Alwife *(Alosa psuedoherangus)*
The alwife is an anadromous fish, living in the ocean and migrating to freshwater to spawn. Juveniles remain in freshwater until mid-fall before migrating to sea.

General Habitat(s)	Marine; riverine;
Pelagic	yes
Thermal Regime	na
Trophic Class	Generalist feeder
Habitat Preference	Gregarious; little is known about their specific habits and movements in Atlantic coastal waters
Reproductive Guild	Nonguarders: Open substratum spawners: Phytophils
Spawning Habitat(s)	Lacustrine; riverine
Spawning Season	Spring
Spawning Months	May-early June
Spawning Temp	~8.8-12.2ºC
Nursery habitat(s)	Lacustrine; riverine
Diet	Freshwater: small invertebrates; Saltwater: planktonic crustaceans, shrimps, and fish larvae
Age at maturity (yrs)	3-4
Adult Length (cm)	~20.0-30.0 TL

American Shad *(Alosa sapidissima)*
The American shad is an anadromous fish, living in the ocean and migrating to freshwater to spawn. Juveniles remain in freshwater until early fall before migrating to sea.

General Habitat(s)	Marine; riverine;
Pelagic	yes
Thermal Regime	na
Trophic Class	Generalist feeder
Habitat Preference	Gregarious; little is known about their specific habits and movements in Atlantic coastal waters
Reproductive Guild	Nonguarders: Open substratum spawners: Phytophils
Spawning Habitat(s)	Lacustrine; riverine
Spawning Season	Spring-early summer
Spawning Months	May-June
Spawning Temp	~14.0-21.0ºC
Nursery habitat(s)	riverine
Diet	Freshwater: small invertebrates; Saltwater: planktonic crustaceans, shrimps, and fish larvae
Age at maturity (yrs)	2-5
Adult Length (cm)	~40.0-50.0 TL

<u>Carp and Minnow Family *(Cyprinidae)*</u>

Common Shiner *(Luxilus cornutus)*

General Habitat(s)	riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	generalist feeder
Habitat Preference	pools near riffles in clear, cool creeks and small to large rivers; preferred water temperature ~30ºC
Reproductive Guild	Nonguarders: brood hiders: Lithophils
Spawning Habitat(s)	riverine
Spawning Season	spring -summer
Spawning Months	May-July
Spawning Temp	~16- 24ºC
Nursery habitat(s)	riverine
Diet	feed mainly at surface or in midwater; opportunistic feeders: aquatic insects both adults and larvae are primary food source, occasionally small fishes and some plant material
Age at maturity (yrs)	1-3
Adult Length (cm)	7-14 TL

Golden Shiner *(Notemigonous crysoleucas)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	generalist feeder
Habitat Preference	clear, weedy, quiet waters of lakes, ponds, reservoirs, pools in slow moving rivers and streams; preferred water temperature~24ºC
Reproductive Guild	Nonguarders: Open substratum spawners: Phytophils
Spawning Habitat(s)	lacustrine; riverine
Spawning Season	summer
Spawning Months	June-August
Spawning Temp	~20-27ºC
Nursery habitat(s)	lacustrine; riverine
Diet	feed mainly at surface or in midwater, feed mainly on zooplankton, adults sometimes feed on insects and small fishes
Age at maturity (yrs)	2-3
Adult Length (cm)	10-15 TL

Bridle Shiner *(Notropis bifrenatus)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	Generalist feeder
Habitat Preference	Weed beds near margins of lakes, backwaters, sluggish weeded streams; slow to moderate current; muddy substrates
Reproductive Guild	Nonguarders: Open substratum spawners: Litho-pelagophils
Spawning Habitat(s)	lacustrine; riverine
Spawning Season	Spring-summer
Spawning Months	May-July
Spawning Temp	~14-27ºC
Nursery habitat(s)	lacustrine; riverine
Diet	tend to feed near bottom and consume small crustaceans, small aquatic or terrestrial insects, algae
Age at maturity (yrs)	1-2
Adult Length (cm)	3.5-5 TL

Blacknose Dace *(Rhinichthys atratulus)*

General Habitat(s)	riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	generalist feeder
Habitat Preference	runs, pools, and riffles; in clear swiftly flowing creeks and small rivers with gravelly substrate
Reproductive Guild	Nonguarders: Open substratum spawners: Litho-pelagophils
Spawning Habitat(s)	riverine
Spawning Season	spring
Spawning Months	May-June
Spawning Temp	~15-22ºC
Nursery habitat(s)	riverine
Diet	feed on a wide variety of aquatic invertebrates and terrestrial insects, aquatic fly larvae are a favored prey
Age at maturity (yrs)	1-2
Adult Length (cm)	6-7.6 TL

Longnose Dace *(Rhinichthys cataractae)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	benthic insectivore
Habitat Preference	Cobble, boulder or gravel riffles of clean swiftly-flowing, creeks and small to medium rivers; rocky shores of lakes; preferred water temperature ~21ºC
Reproductive Guild	Nonguarders: Open substratum spawners: Litho-pelagophils
Spawning Habitat(s)	riverine
Spawning Season	spring-summer
Spawning Months	May-July
Spawning Temp	~11-23ºC
Nursery habitat(s)	riverine
Diet	diet consists primarily of immature aquatic insects that cling to rocks and boulders; chief predator of larval blackflies and midges, but will also prey on other small aquatic invertebrates
Age at maturity (yrs)	2-3
Adult Length (cm)	6.5-11.8 TL

Fallfish *(Semotilus corporalis)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	generalist feeder
Habitat Preference	gravel and cobble bottom pools and runs of small to medium rivers; margins of lakes, ponds, or reservoirs; preferred water temperature ~22ºC
Reproductive Guild	Nonguarders: Brood hiders: Lithophils
Spawning Habitat(s)	riverine: gravel, cobbles; adhesive eggs that stick to the nest
Spawning Season	spring
Spawning Months	May-June
Spawning Temp	~14-19ºC
Nursery habitat(s)	riverine
Diet	omnivorous, eating mostly plankton until they reach~ 1.5 inches in TL, gradually switching to larger foods such as: algae, insects, crayfish, and fishes
Age at maturity (yrs)	3 (m), 4 (f)
Adult Length (cm)	15.5-25.5 TL

Pike and Pickerel Family *(Escidae)*

Redfin Pickerel *(Esox americanus)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	top carnivore
Habitat Preference	typically live in ponds and quiet backwaters of lowland streams; prefers still, shallow waters with dense vegetation; can occur in brackish and acidic waters
Reproductive Guild	Nonguarders: Open substratum spawners: Phytophils
Spawning Habitat(s)	lacustrine; riverine
Spawning Season	spring
Spawning Months	March-May
Spawning Temp	~8-11ºC
Nursery habitat(s)	lacustrine; riverine; swampy, marshy, or flooded areas with abundant submerged vegetation
Diet	juveniles feed on smaller invertebrates and fishes, adults are highly picivorous, large pickerel will eat small mammals, frogs, and snakes
Age at maturity (yrs)	na
Adult Lenth (cm)	30.0 TL

Chain Pickerel *(Esox niger)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	top carnivore
Habitat Preference	typically live in ponds and quiet backwaters of medium to large rivers, less common in smaller streams, can occur in brackish waters
Reproductive Guild	Nonguarders: Open substratum spawners: Phytophils
Spawning Habitat(s)	lacustrine; riverine
Spawning Season	spring
Spawning Months	March-May
Spawning Temp	~8-11ºC
Nursery habitat(s)	lacustrine; riverine; swampy, marshy, or flooded areas with abundant submerged vegetation
Diet	juveniles feed on smaller invertebrates and fishes, adults are highly picivorous, large pickerel will eat small mammals, frogs, and snakes
Age at maturity (yrs)	na
Adult Lenth (cm)	33.0 TL

Bullhead Catfish Family *(Ictaluridae)*

Yellow Bullhead *(Ameiurus natalis)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	warmwater
Trophic Class	generalist feeder
Habitat Preference	pools and backwaters over soft substrates in sluggish creeks and small to large rivers; oxbows, ponds, impoundments and heavily vegetated areas of shallow bays and small lakes; preferred water temperature ~28ºC
Reproductive Guild	Guarders: Nest spawners: Speleophils
Spawning Habitat(s)	lacustrine; riverine
Spawning Season	Spring
Spawning Months	May-June
Spawning Temp	~23-27ºC
Nursery habitat(s)	lacustrine; riverine
Diet	insects, crustaceans, mollusks, and small fishes, as well as some plant material
Age at maturity (yrs)	2-3
Adult Length (cm)	17.8-34.3 TL

Brown Bullhead *(Ameiurus nebulosus)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	warmwater
Trophic Class	generalist feeder
Habitat Preference	pools and sluggish runs over sand to mud substrates in creeks and small to large rivers; impoundments, ponds and lake embayments; preferred water temperature ~25-27°C
Reproductive Guild	Guarders: Nest spawners: Speleophils
Spawning Habitat(s)	lacustrine; riverine
Spawning Season	Spring
Spawning Months	May-June
Spawning Temp	~21-25ºC
Nursery habitat(s)	lacustrine; riverine; young remain in areas with aquatic vegetation through the end of their first summer
Diet	omnivores feed on wide variety of animal and plant material
Age at maturity (yrs)	2-3
Adult Length (cm)	19.3-35.6 TL

Temperate Bass Family *(Percichthydae)*

White Perch *(Morone americana)*
The white perch has a semi-anadromous life strategy; the fish lives its adult life in saltwater estuary habitats and migrates to tidal freshwater and slightly brackish habitats to spawn in the spring.

General Habitat(s)	Lacustrine; riverine; estuarine
Pelagic	semi
Thermal Regime	coolwater
Trophic Class	Top carnivore
Habitat Preference	Brackish bays, river mouths, estuaries, and muddy ponds accessible from the sea
Reproductive Guild	Nonguarders: Open substratum spawners: Phytophils
Spawning Habitat(s)	Lacustrine; riverine; estuarine
Spawning Season	Spring
Spawning Months	May
Spawning Temp	~12.7-14.9ºC
Nursery habitat(s)	Lacustrine; riverine; estuarine; shallow, vegetated or gravel-bottomed shorelines or shallows areas of streams, ponds, or estuaries
Diet	Freshwater: aquatic insects and fishes; Saltwater: shrimps, crabs, small squids, fish fry, and the eggs of other fishes
Age at maturity (yrs)	2-4
Adult Length (cm)	~25.0-35.0 TL

Perch Family *(Percidae)*

Yellow Perch *(Perca flavescens)*

General Habitat(s)	Lacustrine; riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	Top carnivore
Habitat Preference	lakes, ponds and pools of creeks and small to large rivers with moderate aquatic vegetation and clear water, young inhabit weedy shallows, while adults prefer rock ledges usually at depths less than 9 m; preferred water temperature ~ 21°C
Reproductive Guild	Nonguarders: Open substratum spawners: Phytophils
Spawning Habitat(s)	Lacustrine; riverine: weedy areas
Spawning Season	Spring
Spawning Months	April-May
Spawning Temp	~6-12ºC
Nursery habitat(s)	Lacustrine; riverine
Diet	Diurnal carnivores, feeding on small aquatic insects, crustaceans, and small fishes
Age at maturity (yrs)	2-3 (m), 3-4 (f)
Adult Length (cm)	15.2-30.5 TL

Swamp Darter *(Etheostoma fusiforme)*

General Habitat(s)	Lacustrine; riverine
Pelagic	no
Thermal Regime	coolwater
Trophic Class	Generalist feeder
Habitat Preference	Heavily weeded, shallow, protected coves of lakes and ponds; patches of vegetation in fast flowing streams
Reproductive Guild	Nonguarders: Open substratum spawners: Phyto-lithophils
Spawning Habitat(s)	Lacustrine; riverine: weedy areas
Spawning Season	Spring
Spawning Months	May
Spawning Temp	~12-15ºC
Nursery habitat(s)	Lacustrine; riverine
Diet	Small invertebrates and algae
Age at maturity (yrs)	1
Adult Length (cm)	2.5-5 TL

Lamprey Family *(Petromyzontidae)*

Sea Lamprey *(Petromyzon marinus)*
The sea lamprey, an anadromous, jawless fish, enters freshwater to spawn each spring where its juvenile progeny (ammoceote) spend 4-6 years burrowed in the mud filter-feeding on minute organisms before migrating to the ocean as adults.

General Habitat(s)	Marine; riverine;
Pelagic	yes
Thermal Regime	na
Trophic Class	Parasite
Habitat Preference	Little is known about this species specific habitat preferences at sea
Reproductive Guild	Nonguarders: Brood hiders: Lithophils
Spawning Habitat(s)	Riverine; shallow, swift-running, stony stream sections
Spawning Season	Spring-early summer
Spawning Months	May-June
Spawning Temp	~12.0-23.0
Nursery habitat(s)	riverine
Diet	Blood and bodily fluids of host fish
Age at maturity (yrs)	5-8
Adult Length (cm)	~60.0-75.0 TL

Salmon, Char, and Tout Family *(Salmonidae)*

Rainbow Trout *(Oncorhynchus mykiss)*

General Habitat(s)	lacustrine; riverine
Pelagic	yes
Thermal Regime	coldwater
Trophic Class	Top carnivore
Habitat Preference	mid-waters of lakes; creeks and rivers with moderate flow, gravelly bottoms and riffle-pool habitat; preferred water temperature 11.3°C
Reproductive Guild	Nonguarders: Brood hiders: Lithophils
Spawning Habitat(s)	riverine
Spawning Season	spring
Spawning Months	March-May
Spawning Temp	~5-13ºC
Nursery habitat(s)	Hatchery (reproducing populations in New Hampshire na) In Massachusetts reproducing populations are restricted to coldwater streams with high gradient (more than 75 feet per mile)
Diet	Aquatic and terrestrial insects; picsivory in lake dwelling adults
Age at maturity (yrs)	3-5
Adult length (cm)	36.1-73.4 TL

Atlantic Salmon *(Salmo salar)*

The Atlantic Salmon has an anadromous life history. Young salmon remain in freshwater for two or three years, descending to the sea as smolts. At sea, they live for one or two more years before they return to their natal streams to spawn.

General Habitat(s)	lacustrine; riverine; marine
Pelagic	yes
Thermal Regime	coldwater
Trophic Class	top carnivore
Habitat Preference	mid-waters of lakes; rocky runs and pools of small to large rivers; preferred water temperature 16.0°C
Reproductive Guild	Nonguarders: Brood hiders: Lithophils
Spawning Habitat(s)	riverine: highly oxegenated, minimal pollution levels, and silt-free rocky or gravel substrate
Spawning Season	fall
Spawning Months	October- November (return to freshwater typically in May or June)
Spawning Temp	~4-10ºC
Nursery habitat(s)	Riverine
Diet	Young Atlantic salmon feed primarily on aquatic and terrestrial insects while they are in freshwater. Adult Atlantic salmon do not feed in fresh water prior to spawning.
Age at maturity (yrs)	3-6
Adult Length (cm)	53.8-74.4 TL

Brown Trout *(Salmo trutta)*

General Habitat(s)	lacustrine; riverine
Pelagic	yes
Thermal Regime	coldwater
Trophic Class	top carnivore
Habitat Preference	creeks and rivers with moderate flow, gravelly substrates and riffle-pool habitat, and lake shallows; preferred water temperature ~21°C
Reproductive Guild	Nonguarders: Brood hiders: Lithophils
Spawning Habitat(s)	Riverine: spawning substrate with stones ranging from .25-3 inches in diameter
Spawning Season	fall
Spawning Months	October- December
Spawning Temp	~2-13ºC
Nursery habitat(s)	riverine
Diet	juvenile brown trout are primarily insectivorous, until the onset of picsivory
Age at maturity (yrs)	2-4
Adult Length (cm)	25.8-63 TL

Brook Trout *(Salvelinus fontinalis)*

General Habitat(s)	lacustrine; riverine
Pelagic	no
Thermal Regime	coldwater
Trophic Class	top carnivore
Habitat Preference	clear, cool, well-oxygenated streams, ponds and lakes with maximum water temperature less than 22°C; preferred water temperature 16.0°C
Reproductive Guild	Nonguarders: Brood hiders: Lithophils
Spawning Habitat(s)	lacustrine; riverine: gravel riffles coarse sand and stone up to 4 inches in diameter
Spawning Season	fall
Spawning Months	September-November
Spawning Temp	~4-10ºC
Nursery habitat(s)	lacustrine; riverine
Diet	stream dwelling brook trout are primarily insectivores
Age at maturity (yrs)	15.2-44.2 TL
Adult Length (cm)	2-3